Editor's Overview

The 38th issue of the *International Productivity Monitor* contains seven articles. The topics are the impact of trust on productivity; the relationship between zombie firms, exit barriers and productivity; a three-article symposium on the sources of the Transatlantic productivity slowdown; the World Bank perspective on productivity; and productivity measurement in higher education.

Total factor productivity has famously been called a "measure of our ignorance." The concept of social capital has been used to explain TFP, especially TFP differences across countries. The most widely used measure of social capital is trust. In the lead article, **Conal Smith** from Victoria University of Wellington provides a thorough review of the literature on the relationship between trust and TFP and develops new estimates of the impact of trust on TFP. He finds that controlling for trust can have significant effects on TFP. For example, in high-trust New Zealand, moving to the average trust level reduces TFP 6 percentage points from 87 per cent of the US TFP level in 2016 to 81 per cent.

Increased misallocation of resources has been suggested as an explanation for slower productivity growth since 2000. One manifestation of this misallocation is the rise of zombie firms, defined as firms in financial distress. In the second article, **Christian Osterhold** and **Ana Fontoura Gouveia** from the Nova School of Business and Economics use firm-level data for Portugal to examine the impact of the presence of zombie firms on the country's productivity performance. High barriers to exit and restructuring contribute to the growth of zombie firms, with negative effects on productivity. According to the OECD indicator on insolvency regimes, Portugal experienced a large fall in this indicator in recent years, resulting in shorter delays in the initiation of insolvency or restructuring processes. This had the effect on promoting the restructuring of the most productive zombies and the exit of the least productive, boosting productivity through a more efficient allocation of resources.

The ICT revolution is more an American than a European phenomenon. In the third article in the issue, **Robert J. Gordon** from Northwestern University and **Hassan Sayed** from Princeton University examine the role of ICT in explaining productivity growth in the United States and an aggregate of ten EU countries since the 1970s. They show that most of the 1995-2005 US productivity revival was driven by ICT-intensive industries. The paucity of these industries in Europe meant that this region did not enjoy a productivity revival. After 2005, both regions experienced slower productivity growth, suggesting that the benefits of the ICT revolution were short-lived and have not ushered in a new long-term era of faster productivity growth.

The United States is still the world's overall productivity leader, with higher levels of labour productivity than other major economies. In the fourth article, **Martin Neil Baily**, **Barry P. Bosworth** and **Siddhi Doshi** from the

Brookings Institution provide evidence of this reality by examining US productivity performance compared to that of the second and third largest developed economies, Germany and Japan. The authors show that both Japan and Germany were catching up to the US productivity level up to the mid-1990s, with Germany actually overtaking the United States for a brief period. But the acceleration of US productivity growth after 1995, driven by the ICT revolution, reaffirmed the country's role of productivity leader and saw the gap between the United States and Germany and Japan widen.

Productivity growth is affected by both cyclical developments associated with aggregate demand and structural factors such as the underlying pace of technical advance affecting aggregate supply. Determining the relative importance of these factors has always been a challenge for productivity researchers. In the fifth article, **John Fernald** from INSEAD and the Federal Reserve Bank of San Francisco and **Robert Inklaar** from the University of Groningen examine the factors behind the slow pace of productivity growth in Europe. They note that TFP growth slowed before the Global Financial Crisis in 2008-09, suggesting the productivity slowdown has structural as opposed to cyclical roots. On the other hand, they recognize that a strong downturn in the economy can depress productivity growth through a number of channels, including reduced investment, less R&D and labour force hysteresis. But by the second half of the 2010s, they argue that many of these cyclical factors had played themselves out.

A necessary condition for the reduction of global poverty is productivity growth. Given that the World Bank's mandate is poverty reduction, the institution has a strong interest in the productivity issue. In the sixth article, **Don Drummond** from Queen's University and the Centre for the Study of Living Standards provides a critical assessment of the World Bank publication *Productivity Revisited: Shifting Paradigms in Analysis and Policy.* The book uses firm-level data to disaggregate productivity growth into gains within firms, across firms through resource reallocation and through market entry and exit. The analysis is consistent with the World Bank's traditional policy prescriptions related to the creation of favourable business conditions, reduction of distortions, and improvements in human capital to foster productivity growth.

Higher education has been traditionally considered one of the sectors where productivity is "difficult to measure." In the seventh article, **Mary O'Mahony** from King's College London reviews the NBER volume *Productivity in Higher Education* from the perspective of the accountability agenda in higher education. This agenda requires credible and robust measures of performance including productivity measures. The contributors to the volume admirably show that many insights into productivity in higher education can be obtained through the careful use of administrative data, state of the art methodologies, and sound economic reasoning.

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Trust and Total Factor Productivity: What Do We Know About Effect Size and Causal Pathways?

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Abstract

This article explores what is known about the relationship between trust and total factor productivity (TFP). Generalized interpersonal trust is widely considered the best summary measure for social capital, and if this is the case the impact of trust should be reflected in estimates of TFP. A systematic review of the literature on trust, incomes, growth, and TFP finds relatively few articles on the latter despite a developed literature on trust, income, and growth. Using a development accounting framework, a simple model of the relationship between trust and TFP is set out and the size of the impact of trust on TFP is estimated empirically using a cross-country panel dataset based on the European Social Survey (ESS). Despite the limitations of the ESS, estimates of the magnitude of the impact of trust on TFP are broadly similar to those from the only other similar study identified (Bjornskov and Meon, 2015), which is based on the World Values Survey. A counterfactual estimate of TFP is used to illustrate the magnitude of the effect of trust on TFP, highlighting that the impact of trust is non-trivial in real terms, even for high-trust countries.

Interest in the relationship between trust and incomes has a long history. Adam Smith mentions the importance of trust in *The Wealth of Nations* (Evensky, 2011), and Kenneth Arrow famously asserted its importance in 1972, arguing that "virtually every commercial transaction has within itself an element of trust, certainly any transaction conducted over a period of time. It can be plausibly argued that much of the economic backwardness in the world can be explained by the lack of mutual confidence" (Arrow, 1972, p. 357). Although substantive analysis of the relationship between trust, incomes, growth, and productivity is scarce in the economic literature before the 1990s, recent decades have seen a significant body of empirical work emerge.

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Conceptual work linking trust to incomes had its origins largely in the political science literature (e.g. Putnam, 1993; Fukuyama, 1995), but this was soon followed by econometric analyses of the empirical relationship between trust and growth (e.g. Knack and Keefer, 1997; Zak and Knack, 2001) taking advantage of the increasing availability of large cross-country survey datasets containing measures of interpersonal trust (e.g. the World Values Survey). The period from 2000 to 2019 has seen a steady growth in the number of articles on this topic and increasingly sophisticated analysis of the causal relationship between trust and incomes.[2]

The role of trust is particularly of interest in the context of monitoring sustainable development and thinking about issues of growth, consumption, and well-being within an intergenerational context. The capital stocks approach to defining sustainability places emphasis on ensuring that the needs of current generations (current well-being) can be met without depleting the capital stocks that represent the resources available for future production. This approach forms the basis both of attempts to develop a unidimensional metric of intergenerational wealth that can be used to assess the genuine net wealth position of a country (e.g. Arrow *et al.*, 2012) as well as national and international attempts to better understand the trade-offs between current and future well-being (e.g., Treasury, 2018; Smith, 2018; OECD, 2013, 2015). Typically, four stocks of capital are identified: produced capital, natural capital, human capital, and social capital, although knowledge capital is also sometimes added to capture the cumulative impact of innovation and scientific discovery over time.

While produced, natural, and human capital are, albeit to varying degrees, relatively well understood, social capital remains more elusive. It is, however, important. The intangible part of the capital stocks (human plus social capital) account for a large proportion of total variation across countries in GDP per capita (World Bank, 2006; Hamilton and Liu, 2013). In this context social capital is generally taken to be "networks and shared norms, values and understandings that facilitate co-operation" (OECD, 2001). Generalized interpersonal trust is, perhaps, the best candidate measure for this definition of social capital (OECD, 2001, 2017; Scrivens and Smith, 2012). As discussed in the body of this article, and unlike many other proposed approaches to measuring social capital, generalized trust can be clearly defined, measured robustly, and has clear causal pathways whereby it facilitates co-operation and through this contributes to the production process.

Given that standard approaches to calculating total factor productivity (TFP) only address produced capital and human capital (labour), we would expect to see the impact of social capital, and hence trust, reflected in estimates of TFP. This article explores what is known about the re-

2 A search of the Econlit database on the terms "trust" and "growth" shows 51 articles in 2000 and 2001, 48 articles in 2002 and 2003, rising to 120 in 2016 and 2017.

lationship between trust and total factor productivity. The aim is threefold: (1) to summarize what is known from the empirical literature on the size of the relationship between trust and productivity; (2) to articulate what is known about the causal mechanisms whereby trust is thought to affect productivity and growth; and (3) to investigate the plausible magnitude of the impact trust on TFP.

The article has five main sections. Following this introduction, section 1 summarizes the existing literature on the measurement of trust and addresses the validity of trust measures. This is important to the substantive analysis that follows as the credibility of estimates of the trust/TFP relationship depend crucially on whether trust measures are themselves credible. Section 2 sets out the results of a systematic literature review on the relationship between trust, income, growth, and productivity. This includes a brief discussion of the review methodology followed by a more detailed look at estimates of the impact of trust on these outcomes. A discussion of the possible different causal relationships between trust and growth is also included. In section 3 a formal model of the relationship between trust and TFP is outlined and the data that will be used to test this model is discussed. Section 4 presents the results of the empirical analysis and discusses their implications. Finally, section 5 provides a brief conclusion.

Trust and Trust Measures

While information is available on a wide range of different aspects of trust, the focus for this article and for most of the credible empirical literature on social capital is generalized interpersonal trust. This captures a person's belief that other people not known to the respondent can be expected to act in a trustworthy manner (i.e. to act consistently with expectations of positive behaviour). Typically, generalized interpersonal trust is measured through a subjective question like the following:

On a scale from zero to ten, where zero is not at all and ten is completely, in general how much do you trust most people?

While there are a number of minor variations in the precise wording of questions on generalized interpersonal trust used internationally, it is clear that these mostly capture information on the same underlying construct (OECD, 2017; Gonzalez and Smith, 2017).[3] Although the question itself does not specify who "most people" is intended to refer to, it is clear from response data that the question is usually answered with respect to other people within the respondent's community, but not primarily family or friends (Gonzalez and Smith, 2017).

The Economic Relevance of Trust

Before reviewing the literature on the validity of trust measures and the impact of trust on incomes and productivity, it is use-

3 The most commonly used alternative, used in the World Values Survey, asks "generally speaking, would you say that most people can be trusted or that you need to be very careful in dealing with people".

ful to briefly sketch how trust is thought to affect economic outcomes. This serves to flesh out the motivation for looking at trust and productivity as well as providing some context for the discussion of the validity of trust measures. Two examples will suffice to set out the prima facie case that trust affects productivity and hence to provide the motivation for this article.

The core mechanism by which trust is thought to impact productivity is via transaction costs. First, in a high-trust environment, there is less need for costly processes to mitigate risk on the context of moral hazard and principal/agent problems. For example, one reviewer of an early draft of this article who has a role in managing the finances of two organizations noted that in one they are required to obtain a second signature on any cheque over $10,000, while in the other a second signature is not required. These different levels of trust are associated with quite significant levels of labour input and hence productivity due to the time involved in obtaining the second signature.

Trust also affects productivity through confidence. The more risk one associates with interacting with others, the higher the discount rate on investments with a future pay-off. Low trust will therefore tend to create a bias towards short-term investments and interactions with known parties at the expense of potentially more productive uses of resources.

The validity of trust measures

The ability to build a sound understanding of the relationship between TFP and trust depends crucially on the ability to meaningfully measure trust. It is important, therefore, to have a good understanding of the degree to which the standard question on generalized trust described above is a valid and robust measure of peoples' belief that others will act in a trustworthy manner. Given that trust is not something that can be directly observed, this means assessing the degree to which the survey measure of trust used here correlates with other proxy measures of trust (convergent validity).

There are two primary sources of data on interpersonal trust that can be used to assess convergent validity. The first of these involves looking at the correlation between different survey questions on trust and at how responses from different sources vary with respect to trust. The second main source of information on convergent validity lies in the results of experimental studies. There is now a large body of experimental data that can be used to validate survey questions on trust. Finally, although more limited in scope, there is a small body of evidence on the bio-physical correlates of trust that is also relevant.

Knack (2001) provides a good overview of the validity of generalized trust measures from the perspective of convergent validity. He notes, in particular, that data from the *Reader's Digest* 'lost wallet' experiments which involved dropping wallets containing a sizeable (US$50 in 1996) quantity of money in public places across a range of different major cities around the world supports the validity of survey measures of generalized trust. Despite the relatively low sample size for this experiment, the proportion of wallets returned correlates with country values of the WVS measure of generalized trust at 0.65 ($p < 0.01$). When per capita income is controlled for, the correlation is even stronger. This finding has been replicated subsequently (Felte, 2001; Shanahan, 2007) and is reinforced further by Helliwell and Wang (2010) who note that the proportion of lost wallets returned in the *Reader's Digest* experiment correlates well with data from an expectation question on whether a lost wallet would be returned, which in turn correlates well with the WVS generalized trust question.

Looking at a wider range of questions, Knack (2001) notes that responses to the World Values Survey (WVS) question on generalized trust are strongly correlated with items from the same survey relating to respondents' attitudes towards taking advantage of others (e.g. cheating on taxes or not reporting damage to a parked vehicle). These correlations focus on people's assessment of their own trustworthiness rather than on whether other people can be trusted, so the measures are sufficiently different to add substantial information. Knack and Keefer (1997) note that the relationship between generalized trust and attitudes towards taking advantage of others, like that between trust and the proportion of lost wallets returned, is stronger after controlling for per capita income. Naef and Schupp (2009) look at the relationship between people's past trusting behaviour (e.g. lending personal possessions, lending money, leaving the door unlocked) and measures of generalized trust and, using data from the German Socio-economic Panel, find a robust relationship between generalized trust and past instances of trusting behaviour.

Another source of evidence of convergent validity is the correlation between country-average levels of generalized trust and evaluations by foreigners of how trustworthy people from different countries are. Knack (2001) reports that, using Eurobarometer data on "how much you would trust people from different countries", there is a 0.45 correlation ($p=0.056$) with generalized trust measured in the WVS.

Going beyond survey data, there is now a large body of experimental evidence on the validity of measures of generalized trust. This rests largely on lab experiments using one or more variants of the Trust Game (Berg and McCabe, 1995). Glaeser *et al.* (2000) provided the first systematic use of laboratory experiments to validate survey measures of trust. Using a sample of 189 Harvard students, the authors found no significant relationship between the standard WVS measure of generalized trust and trust as measured in the Trust Game. This result is replicated by Lazzarini *et al.* (2004). While this might seem strong evidence against the validity of trust measures, Glaeser *et al.* also find that the survey-based measures of generalized trust are a strong and significant predictor of *trustworthy* behaviour in the Trust Game.

Cox (2004) and Capra *et al.* (2007) explore the relationship between survey-based measures of trust and experimental results in more detail. By including measures of other-regarding preferences — both experimental and survey-based — these authors show that trusting behaviour in the Trust Game is predicted well by the standard WVS question once altruism is controlled for. Finally, Gachter *et al.* (2004) report that the standard generalized trust question is associated with cooperation in the public goods game.

All these studies share one limitation: they use a small and largely unrepresentative sample of participants in the experimental games. This raises the issue of whether the results can be extended to the population as a whole. Johnson and Mislin (2011, 2012) undertake a thorough meta-analysis of experimental studies involving the Trust Game and find a significant positive correlation between the WVS measure of generalized trust and trusting behaviour in experimental games.[4] This finding is replicated in an extension of Johnson and Mislin's work which is able to examine both inter-country and intra-country variation in experimental and survey trust in the same dataset (Carlin, Love, and Smith, 2017). One explanation for this apparent contradiction between the work of Glaeser on the one hand and Johnson and Mislin on the other, is that Johnson and Mislin consider the relationship between country-average levels of trust in both survey responses and experimental results, while the studies citied earlier look at individual-level correlations.[5]

A final source of information to assess the convergent validity of generalized trust measures is provided by Fehr (2009), who discusses a series of experiments analysing the effect of oxytocin (a neurotransmitter highly associated with pro-social behaviour in mammals). In an experimental set-up, players of the Trust Game who received a nasal spray containing oxytocin immediately before the game showed significantly higher levels of trusting behaviour than those who received a placebo spray. Fehr argues convincingly that, in this experimental design, one can effectively rule out the possibility that oxytocin affected trust via affecting player's general altruism or their risk preferences. This study hence suggests instead that the measures of trust produced by the Trust Game capture genuine trusting behaviour and are strongly grounded in a neuro-physical mechanism.

Taken collectively, the body of evidence on generalized trust suggests that such measures capture meaningful information, albeit with some degree of noise. The validity of trust measures is particularly well supported at the aggregate level where there is excellent evidence of convergent validity across countries and regions using a wide range of different metrics including both other survey measures, behavioural data, and experimental results. At the individual level measurement error is a much more significant factor. Although this is a major limitation, it is of less significance than might be initially thought. As will be discussed in the next section, most of the

4 The meta-analysis covers 162 replications of the Berg and McCabe trust experiment across 35 countries and over 23,000 respondents. Although most of these studies are small (the average sample size is 148), they cover a wide range of both developing and developed countries.

5 To understand the apparently conflicting results from Glaeser compared to Johnson and Mislin, consider a simple model where the reported trust ($T_{i,c}$) of individual i in country c is a function of the average actual trustworthiness (W_c) of a person in country c and an error term (ϵ_i) associated with the personality of individual i so that $T_{i,c} = f(W_c, \epsilon_i)$. In Glaeser's within country study there is no variation in W_c so the lack of correlation between survey and experimental trust should be interpreted as showing that the error terms ϵ_i for survey and experimental measures of trust are uncorrelated. Johnson and Mislin (and other similar cross-country studies) allow for W_c to vary as well, and hence pick up a correlation between experimental and survey trust measures.

plausible causal pathways for the impact of trust on productivity are linked to what variation in trust across regions and countries can tell us about expected trustworthiness in different places and the impact of this on productivity and capital accumulation.

Literature Review

Review method

To investigate the relationship between trust and productivity a formal survey of the literature was undertaken. This involved a search on the Econlit database and Google Scholar for articles containing the word "trust" and one or more of the terms "income", "growth", or "productivity"[6].

To be included in the review the articles had to include an empirical estimate of the relationship between generalized interpersonal trust and either the rate of economic growth, levels of per capita income, or a measure of productivity.[7] Table 1 provides a summary of the relevant articles identified through the literature survey.[8] There are 20 articles written between 1997 (Knack and Keefer) and 2015 (Pervaiz and Chaudhary) included in the table. This low number reflects the fact that the number of databases containing information on trust has historically been relatively limited (with the World Values Survey carrying much of the weight prior to the mid-2000s).

The table notes the focus of the study – whether this was the rate of economic growth, levels of per capita income, or some measure of productivity – as well as the nature of the dataset used for the study (cross sectional vs panel data), and the approach to identifying causality (if any). The majority of the articles use cross-country datasets to examine the relationship between trust and economic outcomes, but two studies use within country variation in outcomes (Dincer and Uslaener, 2007; Yamamura and Shin, 2010) and another two use regional variation within and across countries (Beugelsdjik and Van Schaik, 2005; Tabellini, 2010).

For each study included the table lists the coefficient from either the model favoured by the author (where this is clear) or the most fully specified model (i.e. the model including the most complete set of controls). As far as possible the coefficients have been standardized so as to make estimates for different studies comparable. One of the strengths, but also one of the main limitations, of the empirical literature on trust and growth is that many stud-

6 Responses were then manually filtered down to only those producing an empirical estimate of the relationship between trust and either income levels, income growth, or productivity. To ensure that the literature search process did not omit anything important, the bibliographies of the articles identified through the manual scanning were in turn searched for additional references.

7 Ideally this should be a variant of the standard question on generalized interpersonal trust, but other measures clearly focusing on the same concept were included.

8 One potentially relevant recent study – Xiong, Westlund, Li, and Pu (2017) – was dropped from the analysis and is not included in Table 1. Although potentially interesting in terms of looking at inter-regional variation in trust and TFP in China, the study measures trust through a synthetic measure weighting trust and voting through principal component analysis and weighting responses by respondent education. The resulting coefficients are difficult to compare with other studies and the education weights appear somewhat arbitrary.

Table 1: Estimates of the Relationship Between Trust, Income, Growth, and Productivity

Authors	Date	Coefficient	Data	Causality
Trust and GDP Growth Rate *Coefficients are impact of a 1 percentage point increase in trusters in the population on the % change in the GDP growth rate.*				
La Porta *et al.*	1996	**0.0207**	Cross-section	
Knack and Keefer	1997	**0.0820**	Cross-section	
		0.0860	Cross-section	IV
Whitely**	2000	**0.5700**	Cross-section	
Zak and Knack	2001	**0.0630**	Cross-section	
		0.0450	Cross-section	
		0.0600	Cross-section	IV
Beugelsdijk, Van Schaik, and de Groot	2004	**0.0610**	Cross-section	
Beugelsdijk & Van Schaik	2005	0.0110	Panel	RE
Ahlerup, Olsson and Yanagizawa	2007	**0.0668**	Cross-section	IV
Berggren *et al.*	2007	**0.0620**	Cross-section	
		0.0320	Cross-section	
Dincer and Uslaener	2007	**0.0530**	Cross-section	
		0.047	Cross-section	IV
Boulila *et al.*	2008	**0.024**	Cross-section	IV
Dearmon and Grier	2009	**0.048**	Panel	IV
Roth	2009	**0.1800**	Panel*	FE
		-0.0030	Panel*	FE
Tabellini	2010	**0.0600**	Cross-section	IV
Horvath	2012	**0.0300**	Cross-section	IV
Bjornskov	2012	**0.0402**	Cross-section	IV
Pervaiz and Chaudhary	2015	0.0044	Panel	FE
Trust and income levels *Coefficients are impact of a 1 percentage point increase in trusters in the population on $US per capita income.*				
Algan and Cahuc	2010	**316.89**	Panel	FE
Trust and labour productivity growth *Coefficients are impact of a change of 1 in the natural logarithm of the proportion of trusters in the population on the % change in labour productivity.*				
Yamamura and Shin	2010	**0.0500**	Panel	FE
Trust and TFP growth *Coefficients are impact of a 1 percentage point increase in trusters in the population on the % change in the TFP growth rate.*				
Bjornskov and Meon	2015	**0.0049**	Cross-section	IV
Knack and Keefer	1997	0.0127	Cross-section	

Note: IV = instrumental variable; FE = fixed effects; RE = random effects. Coefficients in **bold** are significant at $p<0.05$. Coefficients marked with a * are for the same quadratic equation capturing the effect of trust (0.1800) and trust squared (-0.0030). The coefficient marked ** is on log(trusters) rather than on the percentage of trusters in the country.

ies draw on various iterations of the WVS. This means that many studies face similar constraints in terms of the possible analysis but also means that it is relatively straight forward to produce standardized regression coefficients so that the magnitude of estimated impacts can be compared between studies.

Of the 20 studies included in Table 1 only three focus directly on productivity (Knack and Keefer, 1997; Yamamura and Shin, 2010; Bjornskov and Meon, 2015). Algan and Cahuc (2010) examine the relationship between trust and income levels, while the other sixteen studies estimate the relationship between a 1 percent change in the proportion of people replying “people can usually be trusted” to the WVS generalized trust question or a similar trust measure and the percentage point change in the growth rate of per capita GDP. These latter articles are included here as the effect of trust on productivity is one of the causal pathways hypothesised for the impact of trust on income levels and growth.

Trust and Growth

Focusing first on estimates of the relationship between trust and growth contained in Table 1, the linear specifications range from 0.0044 (Pervaiz and Chaudhary, 2015) to 0.0860 (Knack and Keefer, 1997). Most of these studies (19 estimates from 14 studies) estimate a linear relationship between the percentage of trusting people in the population and the log of the growth rate. Across these 19 estimates, the mean of the coefficients is 0.0456 implying that a 10 percentage point increase in the percentage of trusting people in the population is associated with approximately half a percentage point increase in the annual output growth rate.

Two studies included in Table 1 model a non-linear relationship between trust and growth. Whitely (2000) estimates the relationship between the logarithm of the proportion of trusting people in the population and the log of per capita income growth. The coefficient here implies a broadly similar order of magnitude for the impact of trust on growth as Zak and Knack (2001) or Tabellini (2010) over the range of trust values observed in the WVS but weights increases in trust more highly in environments with relatively low levels of trust. Roth (2009) finds a parabolic relationship between trust and growth, with growth increasing until the proportion of trusting people in the population reaches 30 per cent and declining thereafter.

Only two of the 22 coefficient estimates (Pervaiz and Chaudhary, 2015; Beugelsdjik and Van Schaik, 2005) are not statistically significant in the author's preferred model. Both Berggren *et al* (2007) and Boulila *et al* (2008) undertake systematic robustness testing using extreme bounds analysis (EBA).[9] Findings are mixed, with both studies finding that the sign of the relationship between trust and growth is robust, but Berggren *et al.*'s finding that the statistical significance is not robust in terms of EBA.

The causality column of Table 1 highlights the approach adopted to identifying causality in each study. Of the 22 coefficients for the relationship between trust and growth, 10 have no formal identification strategy other than controlling for the standard independent variables commonly used in the empirical analysis of growth (typically initial income level, the price of investment goods, and a measure of human capital). Another 9 coefficients are from studies that address issues of causality through the use of an instrumental variable. In all cases the instrument used is a historical or geographic feature of the countries in the study. This approach is credible in the sense that the instruments are exogenous and correlated with trust. However, in all cases they are also certainly

9 Extreme bounds analysis tests the sensitivity of coefficient estimates to changes in model specification by systematically re-estimating the model swapping in a large number of different potential independent variables. A coefficient is deemed to pass a hard test of robustness if its sign and significance remain the same in 99 per cent of regressions and a soft test of robustness if they remain the same in 95 per cent of regressions.

correlated with other features of the country that might influence the growth rate such as institutional characteristics or development pathway. In this sense, the instruments provide solid evidence that it is not growth causing trust, but no evidence that it is trust driving growth as opposed to another country-specific factor that might drive both trust and growth.

Only three of the growth studies featured in Table 1 have an identification strategy that addresses these issues. Both Roth (2009) and Pervaiz and Chaudhary (2015) use country-level panel data on trust containing multiple observations for the same countries over time and are therefore able to produce a fixed effects estimate of the impact of trust on growth, while Beugelsdjik and Van Schaik (2005) use a random effects model. Roth, using multiple waves of the WVS finds a significant but parabolic relationship between trust and growth. Pervaiz and Chaudhary, on the other hand, find no significant relationship, but use a substantially different measure of trust to all other studies considered in Table 1 which may partly explain this result.[10] Beugelsdjik and Van Schaik find no impact of trust on growth across European regions but do find a significant positive impact from active civic engagement. However, they express some scepticism as to the generalizability of their results, noting issues in the measurement of trust.

Of the three studies discussed above using panel data to examine the relationship between trust and growth, Roth (2009) considers the widest range of countries over the longest period of time and uses the best measure of trust. However, even taking this into account, the net weight of evidence from these studies for a causal impact of trust on growth must be considered weak. It is for this reason that the study by Algan and Cahuc (2010) looking at the relationship between trust and per-capita income is important. The vast majority of the studies included in Table 1 make use of data from the WVS, which has only 6 waves in total, with the first wave being 1989. Country coverage between waves is inconsistent, creating significant challenges in building a balanced panel dataset of countries for which it is possible to observe changes in trust alongside changes in incomes, growth, or productivity.

Algan and Cahuc circumvent the limitations of the WVS by leveraging the fact that, at the individual level, trust is partly an inherited characteristic. Trust measures are included in the American General Social Survey (AGSS) as is information on country of origin for the respondent, their parents, and their grandparents as well as the date of migration to the United States for each of the above (if a migrant). This makes it possible to estimate the impact of country of origin (self, parents, grandparents) on the trust of survey respondents. Because the date of migration varies, this

10 Pervaiz and Chaudhary use the Index of Interpersonal Safety and Trust developed by the International Institute of Social Studies at Erasmus University as their measure of trust. This index combines over 40 different items from a wide range of sources and includes measures of risk of crime, perceived safety, and limited trust as well as a few measures of generalized trust. Given that generalized trust is only a relatively small component of the index – and that the theoretical grounds for the other elements of the index to affect growth are relatively weak – it is perhaps unsurprising that no significant relationship is identified.

can be used to create a database of trust values at the country level going back to the start of the 20^{th} century grounded in inherited trust.

Focusing on the period from 1935 and 2000, Algan and Cahuc are able to provide a fixed-effects estimate of the impact of a change in inherited trust over this period on GDP per capita. This sits in the development accounting tradition (impact of factor endowments and TFP on incomes) rather than the growth accounting tradition adopted by most of the other articles in Table 1 (which consider the impact of the rate of change in factor endowments on the rate of change in income). Although this makes a direct comparison of the magnitude of the impact of trust on incomes between Algan and Cahuc and the other articles in Table 1 difficult, Algan and Cahuc do provide strong evidence that the relationship between trust and growth is causal (from trust to growth) and that this relationship is not simply proxying for some other country-specific unobserved variable. It thus lends significant strength to the view that the relationship found in other studies is causal.

Trust and Productivity

Although TFP is certainly a significant pathway for how trust affects incomes in all of the studies listed in Table 1 (as will be discussed in the next section), only three studies actually directly estimate the relationship between trust and productivity. Knack and Keefer (1997) investigate the impact of trust on the growth rate of TFP as part of their broader look at the relationship between trust and growth, while for Bjornskov and Meon (2015) TFP is the primary focus of their investigation. Yamamura and Shin (2010) are an outlier among the studies considered here in that they focus on the impact of trust on labour productivity but are valuable in that the Japanese panel data that they use allow for a relatively strong identification strategy by capturing variation in Japanese regions over time.

Knack and Keefer's original analysis found a low positive coefficient for the impact of trust on TFP growth that was not statistically significant within the (small) sample that formed the basis of their analysis. Bjornskov and Meon essentially extend the analysis of Knack and Keefer to a larger sample of countries by drawing on additional waves of the WVS as well as the Latinobarometer, the Asian barometer, and the Afrobarometer and the Danish Social Capital project. As well as increasing the sample size, the wider range of countries provides a better distribution of high, medium, and low trust countries within the sample.

Within the wider sample Bjornskov and Meon find that trust has a statistically significant positive impact on TFP that is robust to a wide range of different specifications and covariates. The size of the coefficient is, however, relatively small, with a 10 percentage point increase in the share of trusters in the population resulting in a 0.05 percentage point increase in the rate of TFP growth. This is consistent with their estimate that, when looking at income levels rather than growth rates, changes to TFP accounts for roughly a quarter of the impact of trust on income while the impact of trust on factor accumulation accounts for the remaining three quarters of this effect. The only situation under which trust was not significantly correlated with the TFP growth rate was when institutional quality was introduced as a covariate. This is unsurprising given that institutional quality and trust are strongly correlated themselves (OECD, 2017). In fact, institutional quality is certainly one of the main mediating factors for how trust impacts other outcomes, with more trustworthy societies generating higher quality institutions in practice and higher quality institutions in turn, reinforcing generalized trust (Uslaner, 2002, 2008).

Causal Pathways

In discussing the causal pathways whereby trust affects incomes, three broad transmission channels are identified in the literature. These are factor accumulation, innovation, and allocative efficiency. Innovation and allocative efficiency represent channels by which trust will affect TFP. The impact of trust on factor accumulation, however, will affect income levels and rate of growth, and while it may affect labour productivity (via its impact on the capital/labour ratio), will not affect TFP.

Factor accumulation captures the impact of trust on levels of investment in produced and human capital. There are two mechanisms at work here. First, high trust societies are associated with better performing institutions. This is because high measured trust implies high average trustworthiness within a society. Strong institutions – particularly strong property rights – in turn create incentives for investment in productive assets (Whitely, 2000; Roth, 2009; Horvath 2012). Investment is inherently an expression of confidence in future states of the world, and the expected rate of return on investment is higher where there is higher confidence that the assets or the income stream resulting from them are not at significant risk of future expropriation. A similar logic applies to investments in human capital. If the risk of nepotism or favouritism in job allocation is seen as low, then the expected rate of return on investment in human capital is higher.

Trust also reduces transaction costs and this too affects investment levels. Roth (2009) notes that high levels of trust facilitate the provision of public goods by reducing the need to expend resources on enforcing compliance. This, in turn, potentially frees up resources for productive investment as well as increasing the range of investment opportunities as some public goods that would be too costly to produce in a low trust setting become viable at higher levels of trust.

A number of the key empirical articles on trust, growth, and productivity explicitly test the importance of factor accumulation on the trust/growth relationship. Knack and Keefer (1997) find that trust is related to measures of capital per worker and human capital, while Dearmon and Grier (2009) find that approximately three quarters of the impact of trust on growth flows through factor accumulation. Bjornskov (2012) finds large effects of trust on human capital, accounting for two thirds of the relationship between trust and growth.

While trust undoubtedly affects incomes through factor accumulation, there are a number of reasons why trust might improve allocative efficiency. Dearmon and

Grier (2009) make the case that higher trust implies fewer resources devoted to protecting property rights and monitoring people in a principal/agent context. This frees up these resources for more productive uses. They also emphasise the role of trust in building better institutions and the flow-on effects of this on allocative efficiency. Stronger institutions and less rent-seeking behaviour allow for less intrusive regulations and therefore fewer resources allocated to monitoring and enforcement. Several authors (Whitely, 2000; Dearmon and Grier, 2011; Horvath, 2012) note that stronger institutions and more secure property rights affects not just the incentive to invest, but also the time horizon for investments. Where there is a low level of confidence in the security of assets and income streams into the future, not only will there be less investment, but investment will also be skewed towards projects with a shorter time horizon.

Another important impact of trust on allocative efficiency occurs through its effect on trade. Here trust again likely acts through reducing transaction costs. International trade always involves an element of trust in that it is likely to require establishing a relationship with business partners potentially operating under a different legal regime. Trade with a high trust country with strong institutions requires less investment in monitoring principal/agent issues and implies a lower risk of expropriation of assets. Butter and Mosch (2003) estimate a gravity trade model using data from Eurobarometer on informal trust to show that a one standard deviation increase in trust is associated with an increase in bilateral trade of between 90 per cent and 150 per cent. In this sense trust can be thought of as reducing the effective distance between different countries for the purposes of trade.

Trust is also believed to affect the rate of innovation. There are two key reasons for this. The first of these is that innovation is partly a function of research, and research is subject to principal/agent problems. In particular, it is difficult and costly for the party commissioning research to observe the quality of the research being undertaken and the effort put in by researchers. In low trust environments this may lead to less investment in research and therefore less innovation (Naastepad and Storm, 2006). Greater trust within firms may also lead to greater continuity of employment and accumulation of 'tacit' knowledge (Kleinknecht, van Schaik, and Zhou, 2014).

The second transmission mechanism from trust to innovation is grounded in the observation that weak ties are important to innovation (Rauch 1993; Dearmon and Grier, 2009). It is through casual interactions with people who may not know each other well or have an ongoing relationship that information diffuses through society. Diffusion of this sort is thought to create opportunities to innovate by applying existing ideas in new contexts. Trust facilitates these sorts of interaction (weak ties). In fact, the standard measure of generalized interpersonal trust (discussed at the start of the first section) is essentially framed in terms of the respondent's level of confidence in weak ties. There are thus strong theoretical grounds for expecting trust to increase information flows and innovation.

Data and Method

The literature reviewed in the previous section is relatively limited from the perspective of understanding the relationship between trust and TFP in that most of it draws from the WVS which contains relatively few country/year observations. As a result, most of the studies are purely cross-sectional and those that are not are forced to draw together trust measures from a range of different sources (e.g. Bjornskov and Meon). In addition, most of the literature focuses on the trust/growth relationship rather than the trust/TFP relationship. In the last decade, however, additional datasets have become available containing high-quality information on trust.

The empirical section of this article makes use of the European Social Survey (ESS), a two-yearly survey of attitudes, values, and beliefs run across 32 countries in Europe since 2002. Using the ESS cumulative dataset gives information on 8 waves of the survey covering 2002 to 2016 and 374,729 responses. For the purposes of examining productivity this was aggregated to produce a cross-country panel dataset containing the proportion of the population with a value on the ESS generalized trust question of 5 or more out of 10 for each ESS wave.[11] Information on TFP was obtained from the Penn World Tables (Feenstra, Inklaar, and Timmer, 2015), covering the same period. The measure used, CTFP, captures the level of TFP relative to the United States with a value of 1.00. As will be outlined below, this is sufficient to model the relationship between trust and TFP.

There are two potential limitations of the ESS data that potentially impact using the data for any analysis of the relationship between trust and TFP. The first of these is that it consists of a sample of European countries. There might therefore be reason for concern that the dataset contains only a narrow range of different cultural models and little diversity in trust. The second potential issue with the ESS data is simply that the time period for the dataset covers only 16 years. Given that trust is likely to evolve relatively slowly over time, this raises the issue as to whether the ESS dataset contains enough meaningful variation in trust within countries relative to noise in the dataset to reach strong conclusions.

Table 2 reports the average level of trust for each ESS country for the first and the most recent waves in which each country participated as well as the difference between these two waves.[12] The Table also presents each country's TFP from the Penn World tables for the same year as the most recent trust observation. It can be observed that the ESS contains a highly diverse set of countries and captures important changes in trust over the period covered. In addition to Western Europe, it

11 This gives a similar proportion of the population in the high-trust group to the "most people can be trusted" response to the widely used WVS question.

12 Data from the New Zealand General Social Survey (NZGSS) is also included for descriptive purposes and in the counterfactual as the NZGSS trust question is comparable to that in the ESS. New Zealand is not included in the causal model as the earliest trust data for the NZGSS dates to 2014.

Table 2: Trust and TFP Data

Country	Trusters in population 2000* (%)	Trusters in population 2016** (%)	TFP level 2016*** (US = 1.00)	Change in trusters (percentage points)
Austria	64	68	0.82	4
Belgium	60	68	0.90	8
Bulgaria	34	34	0.70	0
Cyprus	49	39	0.76	-10
Czech Republic	50	62	0.57	11
Denmark	89	87	0.88	-3
Estonia	69	77	0.60	9
Finland	85	87	0.84	2
France	56	57	0.98	2
Germany	57	67	0.97	10
Greece	37	45	0.64	8
Hungary	51	55	0.55	4
Iceland	82	82	0.90	0
Ireland	70	75	1.10	5
Israel	63	72	0.78	8
Italy	59	58	0.76	-1
Lithuania	72	65	0.71	-7
Luxembourg	71	65	0.79	-6
Netherlands	77	81	0.94	3
New Zealand	-	92	0.87	-
Norway	87	89	0.98	2
Poland	41	50	0.87	9
Portugal	47	53	0.61	6
Russia	45	53	0.51	8
Slovakia	51	45	0.67	-5
Slovenia	47	55	0.60	8
Spain	62	65	0.85	3
Sweden	83	80	0.80	-3
Switzerland	72	78	0.95	6
Turkey	33	22	1.07	-12
Ukraine	52	53	0.45	0
United Kingdom	82	73	0.79	-10

Note: * 2000 or first available observation: 2004 for Estonia, Iceland, Slovakia, Turkey, Ukraine; 2006 for Bulgaria, Cyprus, Russia; 2010 for Lithuania. ** 2016 or most recent observation: 2004 for Luxembourg; 2008 for Turkey; 2010 for Greece; 2012 for Bulgaria, Cyprus, Slovakia, Ukraine; 2014 for Denmark. *** Reports the same year as the most recent trust observation. All data is from the ESS except for New Zealand which is based on the New Zealand General Social Survey. TFP data is taken from https://www.rug.nl/ggdc/productivity/pwt/. The inclusion of Turkey, which has an anomalously high value, has no significant impact on analysis on the results reported elsewhere in the article.

contains data on a wide range of Eastern European countries with different political traditions as well as Cyprus, Turkey, and Israel. A wide range of trust levels are evident in the dataset. In 2000, the lowest level of trust was found in Turkey (33 percent) while the highest level is Denmark (89 percent). In 2016, the most recent year in which data are available, Turkey remains at the lowest at 22 percent but the highest level of trust was reported in Norway at 89 percent. Over the 2000 to 2016 period the net change in trust ranges from a 12 percentage point fall in the share of the population who are trusters in Turkey to an 11 point increase in the Czech Republic. To gain a perspective on aggregate trends in trust between 2000 and 2016 it could be noted that 19 countries out of 30 experienced an increase in the share of the population that are trusters, with 9 countries experiencing a decline and two unchanged.

The Relationship Between Trust and Productivity

Although most modern analyses of the drivers of productivity are grounded in the framework of an endogenous growth model (Romer, 1994), TFP is typically estimated empirically using a simpler framework based ultimately on the Solow-Swan growth model (Solow, 1956; Swan, 1956). In a Solow-Swan framework TFP is calculated as a residual based on the difference between the rate of growth of real GDP per capita and growth in the capital to labour ratio. This being the case, any factors impacting on the growth of GDP per capita not captured in the elements of growth in the capital to labour ratio (essentially the rate of growth of the capital stock and of the labour supply) will end up reflected in the estimate of TFP. Hence, if trust functions as a factor of production, we would expect to see it reflected in TFP.

The article uses a basic development accounting framework to examine the impact of trust on TFP. Equation 1 sets out a basic Cobb-Douglas production function for a country:

$$Y = AK^{\alpha}L^{\beta} \quad (1)$$

where K is the capital stock per worker, L is the mean human capital per worker, Y is output per capita, and A is total factor productivity.

Using the log rule we can convert this to a linear equation:

$$\ln(Y) = \ln(A) + \alpha\ln(K) + \beta\ln(L) \quad (2)$$

We can empirically estimate the model if we have the appropriate data with country (η) and year (θ) fixed effects.

$$\ln(Y) = \eta + \theta + \alpha\ln(K) + \beta\ln(L) + \epsilon \ (3)$$

A comparison of equations (2) and (3) shows that TFP is the residual in equation (3), giving us the identity (4) below.

$$\ln(A) = \ln(Y) - \eta - \theta - \alpha\ln(K) - \beta\ln(L) \quad (4)$$

If we wish to incorporate social capital into this model as an important factor of production we can adapt equation 1 as follows:

$$Y = \hat{A}K^{\alpha}L^{\beta}S^{\gamma} \ (5)$$

where S is social capital and $\hat{A}$ is TFP after adjusting for the impact of trust. Note that social capital in the sense in which it is used here is assumed to be a non-rival good, so per capita social capital is equivalent to total social capital. We can re-write equation (5) in log-linear terms (6):

$$\ln(Y) = \ln(\hat{A}) + \alpha\ln(K) + \beta\ln(L) + \gamma\ln(S) \quad (6)$$

To estimate equation (6) in practice with fixed effects we obtain (7) below:

$$\ln(Y) = \eta + \theta + \ln(\hat{A}) + \alpha\ln(K) + \beta\ln(L) + \gamma\ln(S) \quad (7)$$

which can be re-arranged to give us an identity for $\hat{A}$ (8).

$$\ln\left(\hat{A}\right) = \ln(Y) - \eta - \theta - \alpha\ln(K) - \beta\ln(L) - \gamma\ln(S) \quad (8)$$

A comparison of equations 4 and 8 shows that $\ln(Y) - \eta - \theta - \alpha\ln(K) - \beta\ln(L)$ is equivalent to ln(A), which allows us to re-write equation 4 as follows:

$\ln(A\ ) = \ln\left(\hat{A}\right) + \gamma\ln(S)$ (9)

Although this manipulation of the basic derivation of TFP is straightforward, it highlights two important facts. First, it provides an empirical definition for underlying TFP ($\hat{A}$), defined as TFP where social capital *is treated as a capital stock* (i.e. as a factor of production). In this case $\hat{A}$ can be calculated from the residual of regressing ln(S) on ln(A). This is of some intellectual interest given that the economic models underlying the standard approach to measuring sustainability (e.g. OECD, 2013, 2015; New Zealand Treasury, 2018) implicitly treat social capital as a factor of production.

The second important point is that, if we assume that social capital (of which trust is the best available measure) functions as an important factor of production, then the impact of trust will be reflected empirically in estimates of TFP. One implication of this is that the bivariate relationship between trust and TFP ought to be stronger than the bivariate relationship between trust and GDP.[13] This, as it turns out, is exactly what we see in the empirical data (Algan and Cahuc, 2013).

Estimating equation 9 empirically is relatively straightforward with the aggregate ESS dataset described above. Note that, unlike most of the literature described in section 2, the ESS dataset contains multiple country/year observations so it is possible to adopt a fixed effects specification for the model. In addition, because all of the observations come from the same dataset it is possible to have a high degree of confidence that the results are not influenced by survey effects. This provides a stronger causal attribution than is possible in much of the existing literature.

Only one key decision needs to be made in estimating the model, which is the nature of the functional relationship between trust and social capital. If the relationship is linear then we should estimate $\ln(A\ ) = \gamma\ln(T) + \epsilon$, where T is trust. However, it is also possible that the relationship is non-linear such that T ≈ ln(S). In this case we would estimate $\ln(A\ ) = \gamma T + \varepsilon$. The latter approach appears to be more common as it is the implicit assumption in most of the studies considered in section 3.

Results

Table 3 below presents the results of a series of estimates of equation 9 above with different assumptions about the functional relationship between trust and social capital. Column 1 reports the results of a simple linear regression of the proportion of trusters in the population on TFP.[14] As is expected from theory and prior literature the bivariate relationship is strong and positive. Column 2 adds in country and year

13 To see why this is so consider that changes in real GDP will be a function of changes in the capital to labour ratio, changes in underlying or "actual" TFP (possibly thought of as technological change) and changes in trust. However, changes in measured TFP will be a function only of changes in underlying or "actual" TFP and changes in trust thus removing a major source of noise in the relationship.

14 In the literature drawing on the WVS, a truster is a person replying "people can usually be trusted" in the dichotomous WVS question. As the ESS uses a 0-10 response scale for generalized trust, a truster is defined here as a person with a score of 5 or higher on the ESS generalized trust question.

fixed effects. Once these are added the significance of the relationship drops to the $p<0.05$ level and the magnitude of the coefficient roughly halves. This is unsurprising as, in the absence of fixed effects, trust will be capturing any country-specific factor associated with trust in the cross-section.

Column 3 on Table 3 repeats column 2 but with a one-year lag to TFP (i.e. trust at time t is regressed on TFP at time $t+1$). This provides stronger assurance that any causal effect goes from trust to TFP rather than vice versa. However, introducing the lag in column 3 has little material impact on the coefficient size or significance.

Columns 4 to 6 in Table 3 move from examining the general relationship between trust and TFP to an estimate that can be interpreted in terms of model 9 of the preceding section. In particular, these three estimates follow the wider academic literature and assume that that $T \approx \ln(S)$. The cross-sectional result (4) are largely similar to those obtained from looking simply at trust and TFP, albeit with a slightly larger coefficient. Moving to a fixed effects specification (column 5), we find that the coefficient remains very similar to that in column 2, but the significance drops slightly to just above than the 0.05 level ($p=0.075$). Using lagged TFP makes no real difference to the size or significance of the coefficient.

The coefficient for trust in column 5 is most closely comparable to the equivalent estimate reported by Bjornskov and Meon (2015) in Table 1. The Bjornskov and Meon estimate produces a larger coefficient at 0.00468 than that reported in Table 3 (0.00281), although the two estimates are of the same order of magnitude. This raises the question as to which is the better estimate? Bjornskov and Meon's underlying data covers a wider range of countries including countries at widely differing stages of economic development. By contrast, the ESS dataset has a narrower range of countries, all of which are European or closely associated. However, the ESS dataset has considerably more country/year observations and uses a consistent survey instrument to measure trust across all of them. The larger size of the dataset has the advantage that the estimates in Table 3 include both country and year fixed effects, while Bjornskov and Meon only incorporate country fixed effects. However, the Bjornskov and Meon result is stronger in terms of statistical significance ($p<0.01$ compared to $p<0.1$), suggesting that their result should probably take precedence over the ESS result.

Column 7 of Table 3 reports the results of a regression that assumes $\ln(T) \approx \ln(S)$. This is perhaps the most straightforward interpretation of equation 9 in the method section but is not widely favoured in the academic literature. In practice, however, the functional form makes relatively little difference. The coefficient from column 7 implies a relatively smaller impact from trust on TFP compared to column 5, but this effect is not large.

Counterfactual

While the estimates reported in Table 3 provide support for the view that trust is a significant component of measured TFP, they do not communicate well whether this effect really matters. One way to explore this is to consider a simple counterfactual example comparing the situation of coun-

Table 3: ESS Trust and TFP Regression Results

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent var	TFP	TFP	lag TFP	ln(TFP)	ln(TFP)	lag ln(TFP)	ln(TFP)
Trusters (%)	0.00621***	0.00279*	0.00266*	0.00782***	0.00281∧	0.00254∧	-
SE	0.000838	0.00133	0.00129	0.00108	0.00157	0.00149	-
ln(trusters)	-	-	-	-	-	-	0.144∧
SE	-	-	-	-	-	-	0.084
Country/Year FE	No	Yes	Yes	No	Yes	Yes	Yes
Observations	193	193	193	193	193	193	193
Adjusted R^2	0.220	0.919	0.921	0.213	0.932	0.934	0.932

Note: *** $p<0.001$, ** $p<0.01$, * $p<0.05$, ∧ $p<0.1$

tries with different levels of trust. Panel A in Chart 1 below shows TFP figures for selected countries in 2016.[15] This sees New Zealand with a TFP level, relative to 1.00 in the United States, of 0.87, slightly above the average value in the sample of 0.79. By contrast, New Zealand has the highest measured trust in the sample, with 91.5 per cent of the population reporting a score of 5 or greater on the standard trust question compared to an average of 64.0 per cent (for the unweighted mean of countries in the ESS data). Spain, by way of contrast, has a similar TFP level of 0.85, but a much lower level of generalized trust (65.0 per cent).

Panel B in Chart 1 below recalculates the TFP for each country in the sample as if they all shared the sample average level of trust. In recalculating TFP for Panel B, each country's actual TFP is adjusted using the coefficient from column 7 in Table 2. This is the log/log coefficient which generally gives the smallest effect size. Even with this coefficient, however, it can be seen that there are changes in both TFP levels and country rankings. New Zealand's TFP drops by 0.04 from 0.87 to 0.83, and its ranking drops from 11th to 14th out of 31 countries. Spain's TFP is almost unchanged, and it moves from two places below New Zealand to 2 places above New Zealand.

Panel C illustrates the results of a similar counterfactual to Panel B but using the coefficient from column 5 of Table 2 rather than column 7. This gives a generally larger impact from trust on TFP with the level of New Zealand's TFP dropping by 0.065 to 0.81 Using the coefficient from Bjornskov and Meon the results (not shown) shift New Zealand down another three places to 17th of 31 countries and drop TFP to 0.76 while Spain moves up another place in the rankings.

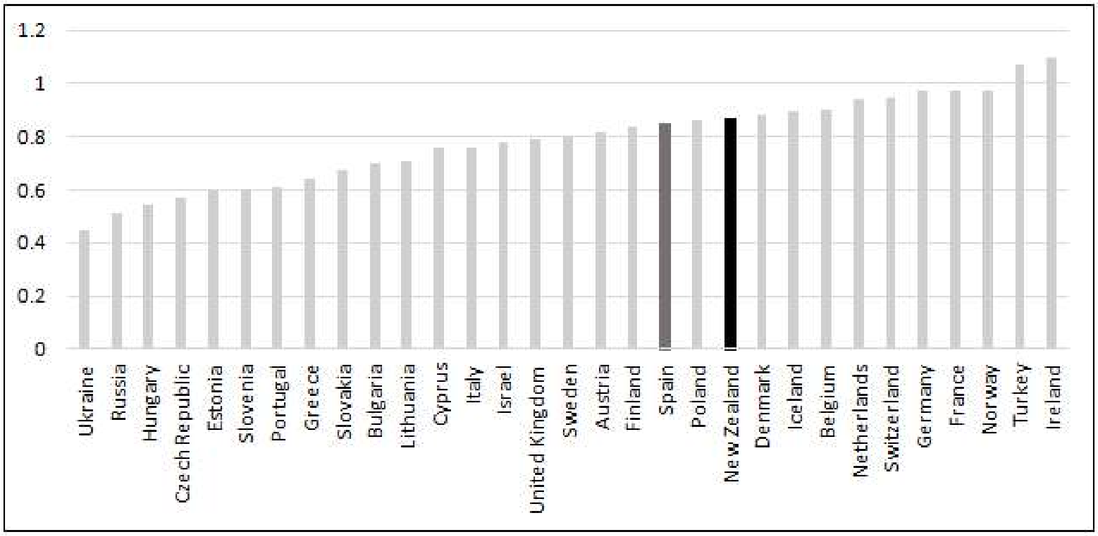
Discussion

The relationship between trust and income growth is robust across studies and it is possible to sketch the main points to emerge from a review of the literature relatively easily. First, estimates of the size of the effect are relatively consistent with a mean effect size of 0.0456. This implies that a 10 percentage point increase

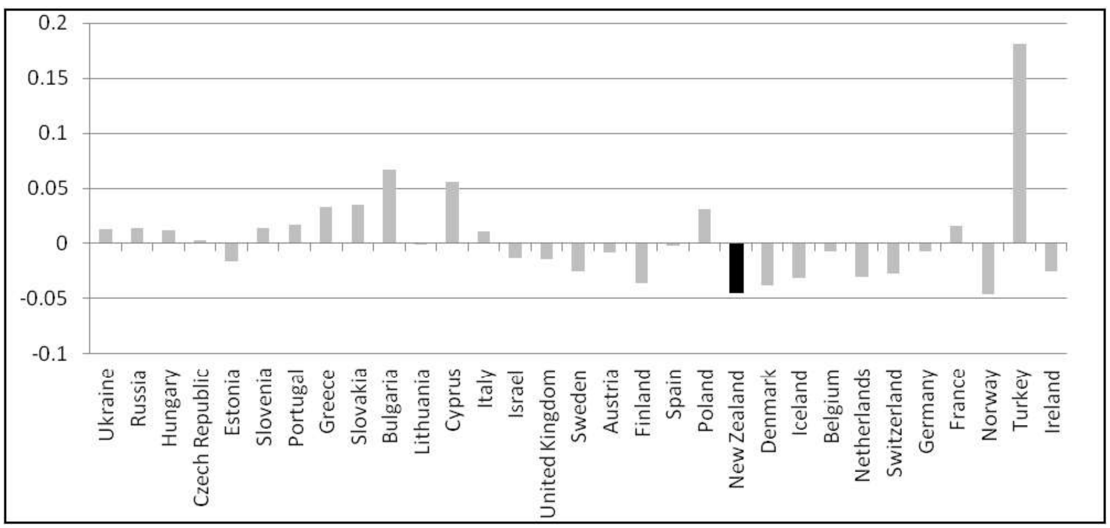
15 All ESS countries with a trust measure more recent than 2006 plus New Zealand which has broadly comparable data for 2014 and 2016.

Chart 1: The Impact of Trust on TFP Levels by Country, 2016 or nearest available year, United States = 1.00

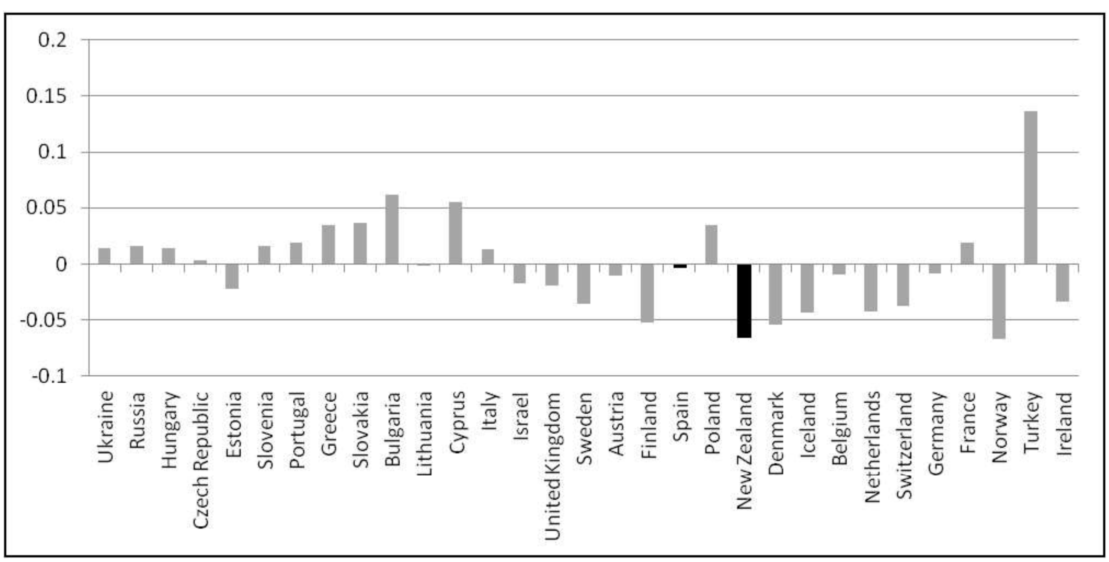
Panel A: TFP by Country



Panel B: Change in TFP by Country after Controlling for Differences in Trust (log on log)



Panel C: Change in TFP by Country after Controlling for Differences in Trust (linear on log)



Source: Penn World Tables. Reference TFP = USA, 2016.

in trusters in the population is associated with an increase in the growth rate of per capita GDP of just under half a percentage point. It is clear that the association between trust and growth does not derive from growth causing trust. The use of instrumental variable approaches as an identification strategy provide convincing evidence of this. However, the nature of the instruments used makes it impossible to eliminate the possibility that it is some other characteristic that varies at the country level which drives both growth and trust.

Data limitations mean that the number of studies able to address issues of causality with greater rigour are rare. Of the four studies included in this review that are able to meet a higher standard of causality, two find no effect (Beugelsdijk and Van Schaik, 2005; Pervaiz and Chaudhary, 2015), one finds a significant parabolic relationship between trust and growth (Roth, 2009) and one finds a strong positive effect (Algan and Cahuc, 2010). As the article with the strongest identification strategy is the article finding the strongest effect, the balance of evidence should be taken as a weak presumption in favour of a causal relationship from trust leading to growth. This view is supported by the analysis of ESS data reported in this article.

All estimates of the relationship between trust and productivity suggest that the direct effect of trust on TFP accounts for only a proportion of the relationship between trust and income growth. About one quarter to one third of the effect of trust on growth goes via TFP while the rest of the impact is via the impact of trust on capital accumulation (human capital or investment in produced capital).

The empirical analysis from the ESS largely supports the earlier Bjornskov and Meon (2009) estimate of the impact of trust on TFP. Although the ESS results are only marginally significant, they are relatively close to Bjornskov and Meon in absolute magnitude (albeit a little smaller). Both the small size of the coefficient and the marginal significance are likely to be associated with the shorter time period and less diverse range of countries covered by the ESS given that generalized trust is a subjective measure and therefore relatively noisy in the short term, while meaningful change is likely to occur only gradually. A counter-factual analysis of the impact of trust on TFP suggests that the impact is meaningful in real terms. A fall in trust of nearly a third (from 91.5 per cent to 64.0 per cent) results in a fall in TFP that is between nearly 8% (ESS) and 14% (Bjornskov and Meon).

Taking these observations into account, there are three issues that are worth highlighting. First, generalized trust potentially matters for public policy in that the impact of trust on economic outcomes is non-trivial. The effect is also asymmetric across countries with different trust endowments. Rothstein and Uslaner (2005) highlight the circular nature of the relationship between trust and institutional quality, with high institutional quality a major determinant of interpersonal trust, and high levels of trust required for the effective functioning of institutions. This suggests that shocks to institutional quality or simply poor performance of institutions might potentially trigger a fall in trust. Although an in-depth analysis of this is beyond the scope of this article, it is worth noting that Ireland and the United Kingdom both saw a marked fall in trust in the ESS dataset following the 2008 recession, while a similar fall is not evident in Denmark or Germany.[16]

The second issue to emerge from the literature review is the weakness of the trust literature at the micro-economic level. While the WVS-based literature along with the work of Algan and Cahuc paints a convincing picture linking trust and economic outcomes at the macro-economic level, there is much less empirical work at the micro-level. Yamamura and Shin (2010) aside, all the studies considered here focus their empirical tests on the net impact of trust at the aggregate level and leave the precise causal pathways to the realm of theory. Ideally it would be good to investigate the impact of trust at the firm and individual level to test the specific causal pathways identified in the literature. Do firms in higher trust environments invest more and for the longer term? Do individuals with higher trust make greater investments in human capital? Can we provide firm-level evidence for the link between weak ties and innovation?

Perhaps the main reason for the lack of empirical micro-economic studies on the impact of trust has been lack of data. The WVS normally has a sample size of about 1,000 individuals per country and lacks any ability to connect trust data to firms or small geographic areas. However, data that could support more detailed analysis is increasingly available with the integration of administrative data on firms and individuals with survey data containing trust measures into integrated research datasets in a number of OECD countries (e.g. Denmark, New Zealand). This offers the ability for a much more nuanced analysis of the relationship between trust and economic outcomes than has been possible in the past and has the potential to shed light on causal pathways at the level of the individual and firm.

Finally, it is worth commenting further on the relative size of the coefficients for trust on growth and on TFP. The larger coefficients on capital accumulation relative to TFP might seem to suggest that it is capital accumulation that is the most important causal pathway for trust on growth (Zak and Knack, 2001). While this is consistent with evidence that capital intensity does account for a large part of variation in labour productivity across countries, the long-term impact of even a moderate impact of trust on TFP is still potentially significant. This observation was the main point of the Swan-Solow growth model (Solow, 1956, Swan, 1956) and, to the extent that this observation is true empirically, then it is the impact on the rate of innovation and therefore TFP growth that is the most significant effect of trust.

Conclusion

Trust certainly matters. Even if one takes a sceptical view of the evidence for

16 Unfortunately a number of the European countries most severely impacted by the 2008 recession such as Greece and Italy simply dropped out of the ESS for the waves after 2008 (Italy) and 2010 (Greece).

causality from trust to growth and productivity, it remains the case that there is a robust association between trust and economic outcomes indicating that trust can be viewed as a proxy measure for whatever it is that does cause growth. It is also the case that levels of generalized trust can change over time. Algan and Cahuc document significant changes in trust over the course of the 20th century across a range of different countries. Using more recent data this is still apparent, with meaningful changes in trust observable in both the WVS and ESS.

This article brings together the available empirical evidence on the size of the relationship between trust, growth, and TFP, and explores the evidence for this relationship being causal. The size of the effect of trust on both growth and TFP is shown to be non-trivial. Although more of the impact of trust on growth goes via capital accumulation rather through productivity, the latter effect remains empirically important. Evidence for causality on the impact of trust is weaker due to data limitations, but the balance of the evidence tilts towards a causal impact.

The empirical analysis in this article strengthens the finding from Bjornskov and Meon that trust is an important component of measured TFP and illustrates the potential magnitude of this impact. The fact that models based on data from the ESS and WVS produce basically similar results despite covering different country samples, time periods, and even trust questions supports the view that the underlying relationship is robust. More generally, the relationship between trust and TFP implied by these results is consistent with the treatment of social capital as a factor of production in the capital stocks model of intergenerational well-being (OECD 2013, 2015).

The existence of trust data in official statistics opens the possibility for studies that directly test some of the causal pathways by which trust is thought to impact on growth and productivity. Regional, firm level, and individual variation in trust could be linked to information on firm level investments in produced capital and in research, as well as to individual variations in human capital accumulation. Such data is also important because it offers the ability to examine the microeconomics of what drives trust. For example, Putnam (1993) theorized that civic engagement builds trust, but there has been limited empirical testing of this hypothesis.

Finally, there is a need for work at the policy level to understand if and how national policy decisions affect social capital. While approaches such as the New Zealand Treasury's Living Standards Framework (New Zealand Treasury, 2018) identify social capital as an asset to be managed, they provide little in the way of guidance on a work programme or what management of social capital means in practice. The results of this article and the wider literature both suggest that the inclusion of social capital as an important asset to be managed is fundamentally correct, and that there are significant risks to not understanding how the dynamics and drivers of trust interact with policy settings. Addressing this should be an important area for economic management agencies.

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Productivity, Zombie Firms and Exit Barriers in Portugal

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Abstract

Productivity growth is slowing in OECD countries, coupled with increased misallocation of resources. A recent strand of literature focuses on the role of non-viable firms "zombie firms" to explain these developments. Using a rich firm-level dataset for Portugal, we explore the role played by zombies in firm dynamics and the misallocation of labour and capital. We confirm the results on the high presence of zombie firms, which are significantly less productive than their healthy counterparts and drag down aggregate productivity. Higher zombie presence is associated with lower growth of viable firms, stifling intra-sectoral capital reallocation. Portugal has shown one of the largest reductions in barriers to exit and restructuring of all OECD countries and is therefore particularly suited for an assessment of the extensive margin effects of these policy changes. We show that a reduction in exit and restructuring barriers promotes a more effective exit channel and fosters the restructuring of the most productive zombies. The results highlight the role of public policy in addressing zombies' prevalence, fostering a more efficient resource allocation, and promoting productivity growth.

Introduction

The last decades have seen enormous progress in information and communication technologies, increased participation of firms in global value chains and a better educated workforce (Peña-López, 2017; Jack and Lewis, 2009). These developments can be seen everywhere but, as aggregate productivity statistics show, global productivity growth is slowing. The "productivity paradox" has raised a debate on the underlying reason. Prominent explanations

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include structural headwinds, the mismeasurement of productivity and fundamental differences between current and past innovations (Adler *et al.*, 2017; Gordon, 2017). Yet, these factors mostly consider headline aggregate productivity numbers and hide possible sectoral heterogeneity.

Firm-level data add an interesting perspective to this discussion: productivity growth has not slowed down for all firms. The most productive (those at the frontier) continue to grow. Meanwhile, the other firms (the "laggards") have stagnated, contributing to a growing performance gap vis-à-vis the frontier (Adalet McGowan *et al.*, 2018; Andrews *et al.*, 2016). Portugal is no exception to this divergence (Chart 1). This pattern is surprising for at least two reasons. First, models of competitive diffusion would predict laggard companies to adopt frontier technology, become more productive and catch-up or, second, in line with the process of creative destruction, forced to exit (Andrews *et al.*, 2016).

On the diffusion models, the literature points to a breakdown of technological diffusion mechanisms, translating into "winner takes it all" dynamics — where one or a few firms dominate the market. Firms below the technological frontier are no longer able to learn from top-performers and therefore cannot catch-up and grow (Autor *et al.*, 2017; De Loecker *et al.*, 2020; Grullon *et al.*, 2019; Blonigen and Pierce, 2016; Reich, 2016; Krugman, 2015).

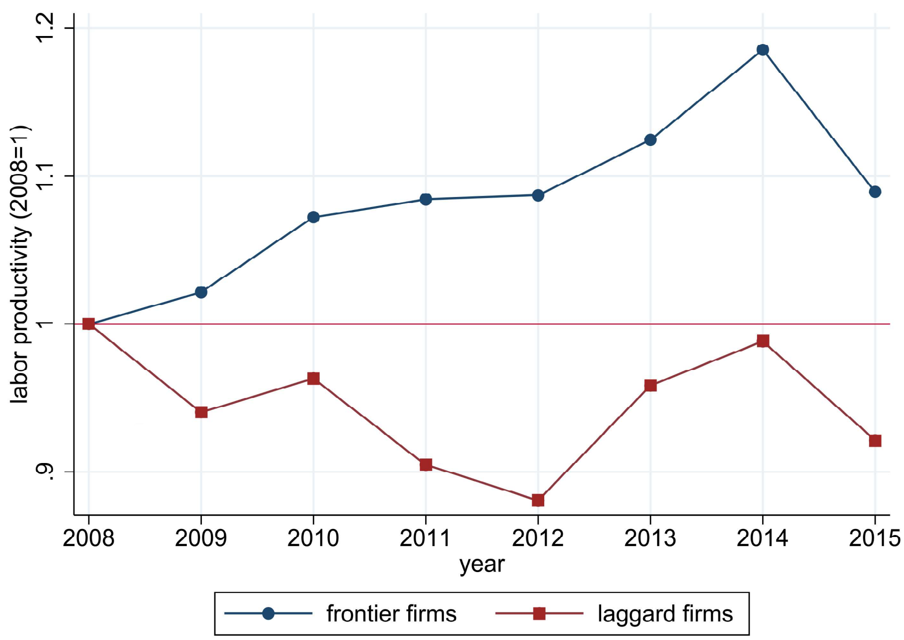
On the predictions of Schumpeterian creative destruction, an increasing body of research uncovers rising capital and labour misallocation, in particular within industries, being a major driver of the productivity slowdown (Cette *et al.*, 2016; García-Santana *et al.*, 2016; Gopinath *et al.*, 2017; ECB, 2017; Lenzu and Manaresi, 2018; Andrews and Petroulakis, 2017). This trend is visible for Portugal, both across sectors (Reis, 2013; Benigno and Fornaro, 2014) and within sectors (Dias *et al.*, 2016; Gopinath *et al.*, 2017) — with within industry misallocation almost doubling between 1996 and 2011. Increased misallocation is linked with curtailed firm dynamics, where the least productive can remain in the market, capture resources, and thus stifle the entry and growth of viable firms (Criscuolo *et al.*, 2014; Decker *et al.*, 2016).

A recent strand of literature, led by the OECD, links these developments to the emergence of zombie firms (Adalet McGowan *et al.*, 2017a/b, 2018).[2] Institutional bottlenecks create the conditions for non-viable firms to remain in the market as a result of depressed creative destruction.[3] By remaining in the market, despite their low productivity, these persistently weak firms increase productivity dispersion and drag aggregate productivity down. Their negative spillovers on viable laggard firms and potential entrants add to the dispersion. Zombies crowd out available financing and human capital and distort compe-

2 The OECD work builds on work for the Japanese economy (Caballero *et al.*, 2003; Hoshi and Kashyap, 2004; Caballero *et al.*, 2008).

3 Recent research also highlights the role of the banking sector for zombie prevalence, promoting resource misallocation and curbing productivity growth (Duval *et al.*, 2017; Storz; *et al.*, 2017; Acharya *et al.*, 2019; Schivardi *et al.*, 2017; Blattner *et al.*, 2018).

Chart 1: Labour Productivity Developments in Portugal, 2008-2015 – Frontier vs. Laggard Firms



Source: Authors' own computations based on firm-level data from IES.
Notes: Labour productivity defined as gross value added per worked hour. Frontier firms are the top 10 per cent most productive companies in each two-digit sector (non-financial and non-farming 2-digit NACE Rev. 2) in each year. Indices are computed at industry level and averaged across industries.

tition in product and input markets, by depressing prices, inflating market wages and reducing the market share available for viable firms to invest and grow (Caballero *et al.*, 2008; Adalet McGowan *et al.*, 2018; Schivardi *et al.*, 2017).

This article uses a set of comprehensive firm-level data for Portugal, a country with weak aggregate productivity growth (Alves, 2017), covering all firms from 2006 to 2015, we contribute to the literature on the role of zombie firms in explaining resource misallocation, by reinforcing the evidence on negative spillovers on healthy firms (intensive margin). Furthermore, we provide novel evidence on the role of policy barriers on the extensive margin. Portugal, as one of the OECD countries with the largest decrease in exit and restructuring barriers in recent years (Chart 2), provides a quasi-natural experiment to understand the institutional drivers of zombie prevalence. Studying zombie spillovers in a country that underwent a deep crisis brings additional insights into the literature as externalities may be higher, given the more restricted supply of credit, amplifying the crowding-out effect. The coverage of our database, which includes all Portuguese firms, is an improvement vis-à-vis studies that focus only on listed firms. It solves the possible selection bias in cross-country studies that use samples where specific industries and smaller, younger firms are underrepresented. The results for Portugal are relevant for a number of countries, as the increased misallocation is a widespread phenomenon, and the zombies' characteristics and prevalence display cross-country regularities (Adalet McGowan *et al.*, 2018).

We confirm the results in the literature on the high presence of zombie firms. Zombies are significantly less productive than their healthy counterparts, increase productivity dispersion and drag aggregate productivity down. While there is evidence of positive selection within zombies, with the most productive restructuring and the least productive exiting, we also find that zombies' productivity threshold for exit is much lower than that of viable firms, allowing zombies to stay in the market, distort competition and capture resources. This curbs the growth of viable firms, in particular the most productive, harming within industry resource reallocation. We show that a reduction in exit and restructuring barriers promotes a more effective exit channel, disproportionately facilitating the exit of non-viable firms, and fostering the restructuring of the most productive within zombies. Our results highlight the role of public policy in promoting an improved resource allocation within sectors and thereby unlock productivity growth.

The remainder of the article is organized as follows. Section 2 reviews the literature on zombie firms, including a discussion on the quantitative criteria to define a zombie. Section 3 elaborates on the rich set of data used in the analysis, and Section 4 takes stock of the characteristics of zombie firms and their dynamics. The empirical framework for assessing the impact of zombie congestion on non-zombie firms and the impact of policy-induced barriers on zombies' exit and restructuring is developed in Section 5, where we also present and discuss the results. Section 6 concludes, discussing avenues for future work and possible policy complementarities.

Literature Review on Zombie Firms

A Prior on the Definition of Zombies

In economic terms, a zombie is a non-viable firm that would exit or, where feasible, restructure in a competitive market. The literature offers different definitions to operationalize this concept (Adalet McGowan *et al.*, 2018).

Caballero *et al.* (2008) consider a firm to be a zombie if it receives financial help from its creditors to survive, despite poor profitability. In practice, the authors compare the interest rate paid by the firm to a reference interest rate, that of the highest-quality borrowers. Those firms with a negative interest rate gap receive subsidized credit and thus are classified as zombies. The method is very data demanding, implying detailed knowledge of each firm's debt distribution.

Other authors rely on the operating characteristics of the firm. Storz *et al.* (2017) classify a firm as a zombie if it shows a negative return on assets and negative net investment for two consecutive years and a debt-servicing capacity (EBITDA to total financial debt) lower than 5 per cent. Schivardi *et al.* (2017) combine two criteria: return on assets below the cost of capital for the safest borrowers (three-year average) and financial debt over assets above 40 per cent (also testing alternative thresholds). Bank of Korea (2013) classifies a firm as a zombie if the operating income (EBIT) is lower than interest expenses for at least three consecutive years. Building on this definition, the OECD add the age criterion that firms need to be older than ten years, to avoid erroneously classifying start-ups as zombies (Adalet McGowan *et al.*, 2018).

In this article, we follow the OECD definition. We use a simplified EBIT measure to address an accounting standard change in the dataset (see Section 2.1). The three-year criterion is essential in addressing the pro-cyclicality concerns on the zombie status (also addressed with the sectoral-time fixed effects included in the regressions that follow). Given the severity of the crisis that impacted Portugal, we also test for a more stringent time criteria, imposing five years. Moreover, to have a more symmetric measure on the non-zombie status, we compute an alternative specification where firms, once declared zombies, can only become non-zombies after three periods of interest coverage ratios higher than one. On the criticism that the analysis omits firms which exit the market before completing ten years, it should be noted that the objective is not to focus on unhealthy firms, but on unhealthy firms that endure in the market. That is the very definition of a zombie firm.

In any case, it is not likely that the results depend critically on the criteria chosen as they are broadly consistent. By computing a simplified version of Caballero *et al.* (2008) methodology, Adalet McGowan *et al.* (2018) show a positive and significant correlation with their definition. Storz *et al.* (2017) and Schivardi *et al.* (2017) replicate their results using the interest coverage ratio criteria followed by the OECD, with limited impact on the results. Adalet McGowan *et al.* (2018) also test for different variations of their criteria, again with no major changes. These results highlight that more important than the level of zombie congestion — which is different for different criteria — what matters are the dynamics of zombie prevalence across time and sectors.

Existing Results on Zombie Firms

Historically, the academic analysis of zombie firms originated with the Japanese macroeconomic stagnation in the 1990s (Hoshi and Kashyap, 2004; Caballero *et al.*, 2008), but there are even earlier references (Kane, 1989). Caballero *et al.* (2008) argue that zombies in the Japanese economy reduce market prices, increase market wages and congest markets, reducing profits, discouraging entry and investment, and limiting viable firms' expansion. The authors show a sharp increase in zombie prevalence in the early 1990s, stabilizing at high levels from the mid-1990s to 2002, the end year of their sample. By relying on a reduced form model of spillovers of zombie congestion, the authors show that a higher share of capital sunk in zombie firms reduces the growth differential of healthy firms vis-à-vis zombies.

Building on this work, a series of OECD papers analyze the zombie phenomenon for a sample of OECD countries over the period 2003 to 2013. Adalet McGowan *et al.* (2018) show that the share of total employment and capital stock accounted for by zombie firms, as well as the share of zombie firms in the total firm population, has risen in several OECD countries. This increase, coupled with the fact that zombies, on average, own more capital and employ more workers than non-zombies, translates into high shares of resources sunk in non-viable firms.

The increased zombie prevalence is a widespread phenomenon in OECD countries, particularly among European countries, with a steady decline in interest rate coverage ratios since 2011, despite the low-interest-rate environment (IMF, 2017; Mahtani *et al.*, 2018). The spillover mechanisms detailed in Caballero *et al.* (2008) are corroborated for OECD countries. Within industries, the capital sunk in zombies reduces employment growth and investment for the average non-zombie in relation to zombies, and more so for the most productive firms, harming the process of resource reallocation (Adalet McGowan *et al.*, 2018). The reduced investment by non-zombie firms stifles innovation and technology advances, also depressing within-firm productivity growth (Cooper *et al.*, 1995; Adalet McGowan *et al.*, 2018).

An increasing body of literature deals with the link between the financial sector and the prevalence of zombies. Financial frictions harm the most vulnerable firms — i.e. those with higher rollover risk, higher debt overhang or lower collateral — which are not necessarily the least productive (Duval *et al.* 2017). Also, financial frictions, in particular when exit barriers are high, foster the survival of firms that would otherwise exit the market via bank forbearance to avoid the realization of losses. Weaker firms are associated with weaker banks (Blattner *et al.*, 2019; Storz *et al.*, 2017; Schivardi *et al.*, 2017; Acharya *et al.*, 2019; Arrowsmith *et al.*, 2013). Relationship banking is also a potential factor fostering zombie lending, as zombies are on average older (Peek and Rosengren, 2005). Furthermore, there is again evidence of negative spillovers, as the restricted credit availability reduces the exit of non-viable firms at the expense of healthier firms (Schivardi *et al.*, 2017 and Anderson *et al.*, 2017).

Exit and restructuring barriers play an important role in zombie congestion and for productivity growth.[4] Evidence suggests that better insolvency frameworks are associated with a higher likelihood of zombie restructuring, higher TFP growth for laggards (by providing incentives to experimentation and by allowing for easier structural changes at the firm-level) and reduced zombie congestion (Adalet McGowan *et al.*, 2017a/b). Additionally, they incentives banks to encourage corporate restructuring (Andrews and Petroulakis, 2017). This is particularly relevant given that healthy firms have more difficulties accessing credit in markets with higher zombie prevalence and that improvements in bank health are more likely to reduce zombie congestion when insolvency regimes are of better quality (Andrews and Petroulakis, 2017).

4 Even though there is heterogeneity in zombie presence across countries, potential gains to productivity by improving insolvency regimes are also high for countries which show relatively low levels of zombie congestion (Adalet McGowan *et al.*, 2017a).

Table 1: Descriptive Statistics for Portuguese Firm-Level Data, 2006-2015

Variable	Unit	Mean	Median	Std. Dev.	Min	Max
Revenue Turnover	1000 Euros	1.349	152	27.501	0	9,699,709
GVA	1000 Euros	289	44	4.934	-150.234	1,287,741
Worked Hours Per Year	hour	21.039	6.336	195.607	961	37,989,600
Total Workers	unit	12	4	108	1	23.768
Tangible Assets	1000 Euros	444	22	15.699	0	4,646,097
Intangible Assets	1000 Euros	82	0	8.289	0	2,964,748
EBIT	1000 Euros	39	2	2.315	-379.964	792.503
Interest paid	1000 Euros	25	1	1.229	0	783.815

Source: Authors' own computations based on IES.

Data

Firm-level Data

We rely on a comprehensive set of firm-level data for the period 2006 to 2015, the Informação Empresarial Simplificada (IES) provided by Banco de Portugal. IES covers the entire population of Portuguese firms, including profit and loss and balance sheet data. The data used in this article cover NACE Rev. 2 industry codes 10-83, excluding 64-66.[5] After data treatment, the unbalanced panel dataset includes 343,180 firms and 1,875,545 observations.[6] Table 1 provides descriptive statistics for the firm-level data used in this article.

To apply the zombie classification, we compute the interest coverage ratio as earnings before interest and tax (EBIT) divided by interest expenses. EBIT as reported IES has a break in 2010, because of a change in accounting standards. To overcome this, we compile a simplified EBIT measure — turnover and subsidies to production net of cost of goods sold, services and external supplies, labour costs and depreciation. It excludes financial income due to the difficulties in compiling a consistent time series and thus it is a less stringent zombie definition in comparison with that used by the OECD.

Labour productivity is defined as nominal gross value added (GVA) per hour worked. We calculate nominal GVA as the sum of turnover and operating subsidies, minus cost of goods sold and supplies and external services, following Banco de Portugal (2014). Robustness checks with GVA per worker are also performed. Intangible assets are only included for the robustness checks, given the change in accounting rules and due to measurement issues and (under)reporting of intangibles. To limit the impact of outliers in the regression analysis, we focus on firms with at least three workers and exclude the percentiles 1 and 99 of the dependent variables (capital

5 This restriction excludes either industries that are providing public services (i.e. education and healthcare) as their business models not primarily focus on profit maximization or industries in which the measurement of labour productivity developments is difficult and would bias the results. The following sectors are excluded: agriculture, forestry and fishing; mining and quarrying; financial and insurance activities; public administration and defense, compulsory social security; education; human health services; residential care and social work activities; arts, entertainment and recreation; other services; activities of households as employers; activities of households for own use; and activities of extraterritorial organizations and bodies.

6 See Gouveia and Osterhold (2018) for more information on data treatment.

and employment).

Data on Exit and Restructuring Barriers

To study the link between insolvency regimes and firm dynamics, we use the country-level OECD composite insolvency indicator, ranging from 0 to 1. When the composite indicator is high, i.e. close to 1, the relatively high exit and restructuring costs most likely lead to a delay in the initiation of the insolvency or restructuring process and prolong the duration of the proceedings, incentivizing unviable firms to stay in the market (Adalet McGowan *et al.*, 2017a).[7] The indicator is available for 2010 and 2016 and is a combination of 12 different sub-indicators (Adalet McGowan *et al.*, 2017b). Portugal registered one of the most substantial improvements among OECD countries in recent years (Chart 2). Major changes occurred in 2012, in the context of the 2011-2014 Economic Adjustment Programme. The reforms, inspired by the US insolvency framework (the famous Chapter 11), aimed at fostering the recovery of viable firms and the liquidation of non-viable ones.[8] Based on the dates of these changes, we annualized the OECD indicator in order to build an annual time series capturing exit and restructuring barriers.

Industries with higher natural firm turnover rates, i.e. those with more entry and exit, are more exposed to policy-induced insolvency regime changes than industries with lower turnover rates. Data on industry-level firm turnover rates of the UK and the United States markets, which are relatively unregulated and approximate natural turnover rates, are used to measure the exposure of each industry (Bottasso *et al.*, 2017 and Adalet McGowan *et al.*, 2017b).

By using turnover rates for the UK and the US, we account for endogeneity issues as the industry-level firm turnover rates in Portugal are dependent on the existing structural policies and, in particular, on the existing insolvency framework.

The industry-level measure of exit and restructuring barriers is computed as:

$$Barriers_{s,t} = InsolvencyFramework_t * NaturalTurnoverRate_s^{uk,us}$$

where the annualized insolvency indicator, $InsolvencyFramework$, is weighted by the proxied *natural* industry turnover rate $NaturalTurnoverRate$ of the UK or, as a robustness check, of the United States.

Zombie Presence and Prevalence

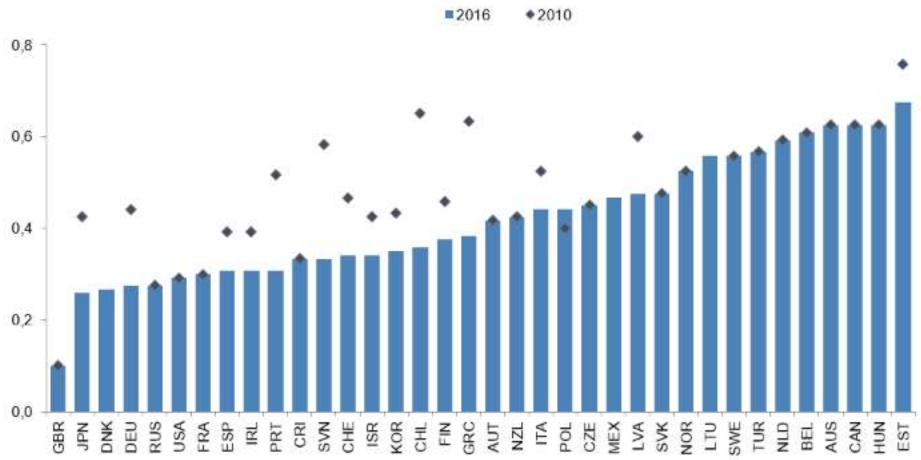
Following Adalet McGowan *et al.* (2018), we define zombie firms as those that are at least ten years old and whose interest coverage ratio is smaller than one

7 The indicator is a de jure measure, focusing on the quality of the framework in each country. Although the OECD also collects some information on outcome measures, it is difficult to build a comparable de facto indicator on a cross-country basis.

8 See Gouveia and Osterhold (2018) for more information on the reforms.

9 Alternative specifications are tested to check robustness.

Chart 2: OECD Indicator on Insolvency Regimes: 2010 and 2016



Source: OECD. Notes: An increase in the composite indicator most likely leads to a delay in the initiation of the insolvency or restructuring process and prolong the duration of the proceedings.

for at least three consecutive years.[9] This section provides an overview of the patterns of zombie prevalence over time and of the characteristics of zombie firms.[10]

Our data show a positive correlation between size and labour productivity in all but four 2-digits sectors (from a total of 63 sectors) — hinting that, within each sector, the most productive firms are able to grow. However, there are also signs of increased intra-sectoral misallocation, with increases in the within-sector interquartile range and standard deviation of labour productivity, suggesting problems at the exit margin. An analysis of zombie firm patterns confirms this. Zombies are more likely to leave the market, with an average exit rate of 13.3 per cent (10.7 per cent for non-zombies; 7.9 per cent if one considers those in the same age bracket as zombies, i.e. 10 years or more). Yet, zombie firms that exit have a labour productivity around 100 per cent below the average productivity in the sector (which means that they have around zero labor productivity), while the average non-zombie leaving the market is 30 per cent below average. Conversely, while the average non-zombie that remains in the market is 9 per cent more productive than the sectoral average, for zombies the deviation is negative (-50 per cent).

While the zombie status is quite persistent, with more than two-thirds of zombies remaining zombies in the subsequent two years, there is also evidence of positive market selection within zombies, with the less productive exiting and the most productive restructuring.[11] However, these positive market forces do not hold across zombies and non-zombies. Zombies remain in the market even if they are half as productive as the average firm in their indus-

10 Data are available as of 2006; hence the zombie classification can be applied from 2008 onwards, the first year in which a firm could possibly trespass the "three consecutive years" condition.

11 Firms that restructure are defined as those that were zombies in t_{-1} and managed to become non-zombies in t and remain healthy in t_{+1}.

try. In general, while firms that exit are, on average, less productive than those that stay (in relation to the sectoral average), the labour productivity deviation threshold for exit is much more lenient for zombies.

From this analysis, one expects zombie firms to be rather prevalent in the economy.[12] Overall, zombies represented around 6.5 per cent of all Portuguese firms in 2008, increasing steadily to 8.5 per cent in 2013. This pattern is similar to that of other countries, such as Spain, Belgium and Italy (Adalet McGowan *et al.*, 2018). Since 2013, the relative number of zombies decreased to close to 6 per cent in 2015. These figures are, however, poor measures of zombie prevalence. As illustrated in Table 2, zombie firms are not only less productive than their healthier counterparts (average deviation towards the 2-digits sectoral mean), but they are also larger — in terms of employment, turnover and assets — and older.[13]

Thus, zombies' economic relevance is better ascertained with measures of capital and labour sunk — i.e., the share of resources that they capture. Given substantial sectoral heterogeneity (as also described by Caballero *et al.*, 2008), Chart 3 presents sunk resources aggregated by main sector of activity, comparing the evolution from 2013 (where the share of zombies in the overall economy reached its maximum) to 2015 (the most recent period). The chart shows that capital is more flexible, with more variation over time than labour.[14] Overall, results of the descriptive analysis are consistent with OECD findings, pointing at cross-country regularities. Zombie firms are on average larger — in terms of employment, turnover and assets — and significantly less productive than their healthy counterparts. Furthermore, there is evidence of distortions at the exit margin, as zombies remain in the market and absorb a significant part of capital and labour, with differences across industries.

Empirical Framework

As shown above, zombie firms are less productive than their non-zombie counterparts and account for a non-negligible part of capital and labour, providing evidence of misallocation of resources towards non-viable firms. It is thus important to understand the possible adverse effects of zombie congestion on healthy firms' growth. We explore the sectoral asymmetries to analyze the consequences of zombie congestion on intra-sectoral resource allocation (intensive margin) and, also, to assess the role

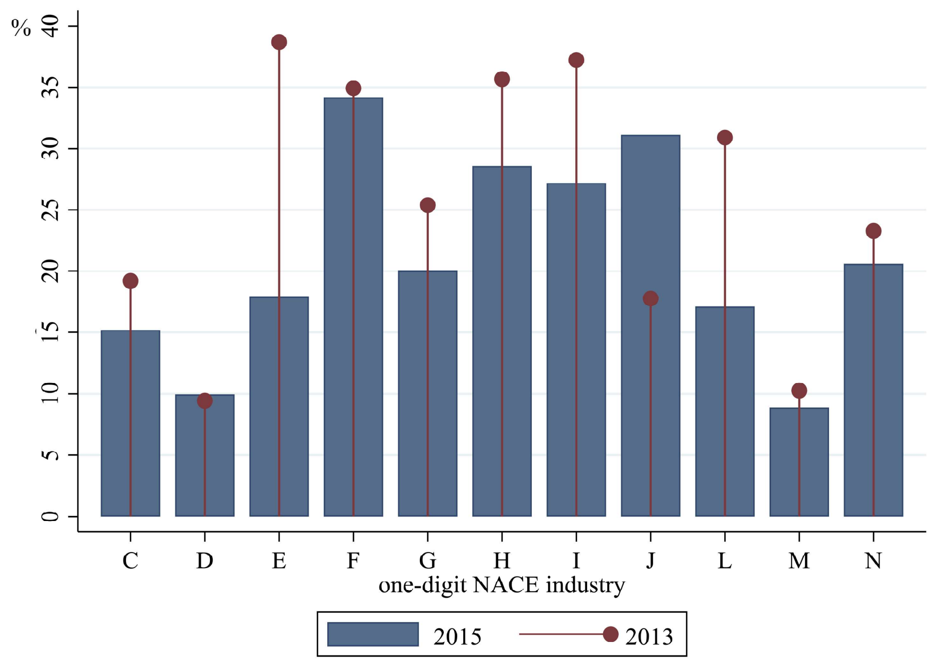
12 Note that a direct comparison with other studies is difficult as the universe of firms considered does not coincide and the quantitative measures to define zombies vary. For these reasons, a qualitative comparison of dynamics is more appropriate than a direct comparison of levels.

13 These characteristics make it easier for them to obtain access to credit, as they have more collateral, in the form of tangible assets, and are more likely to have longer relations with banks. Gopinath *et al.* (2017) find that capital is allocated to firms with higher net worth, not necessarily the more productive. Being larger in terms of employment also implies high social costs from failure, which, as argued by Adalet McGowan *et al.* (2018), may make them more likely to receive government subsidies or support in order to limit potential employment losses, in particular during recessions.

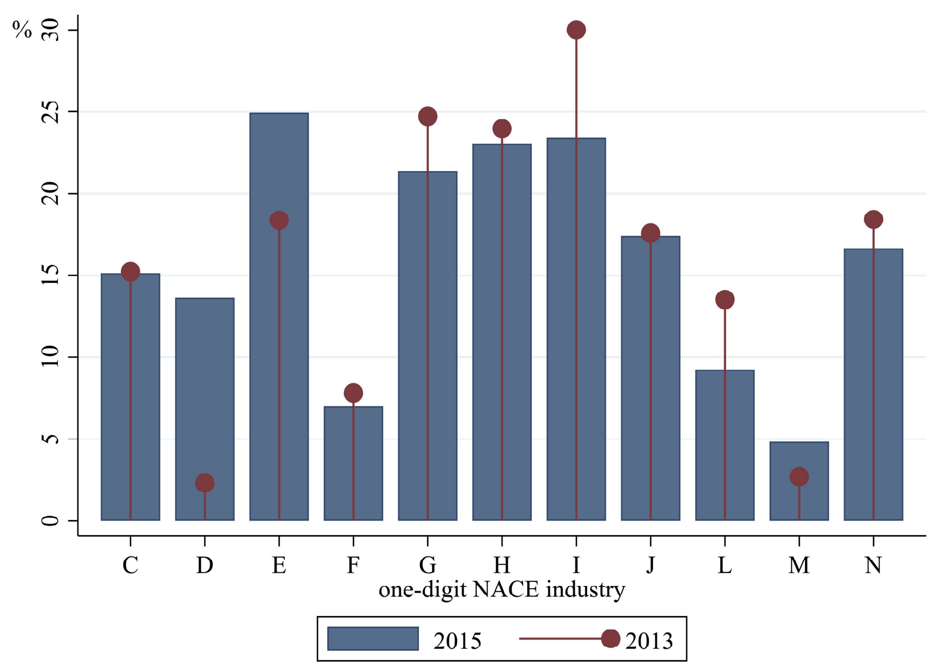
14 As explained before, the level varies with the use of more or less stringent zombie definitions. Therefore, the analytical focus should be on the time dynamics and the sectoral differences, which are broadly robust to the zombie definition.

Chart 3: Share of Labour and Tangible Assets Sunk in Zombie Firms, Industry Level

Panel A: Tangible Sunk Capital



Panel B: Sunk Labour



Source: Authors' own computations based on IES.
Note: For presentational purposes, we aggregate data at the CAE letter code level. In the analytical part, we use the more detailed 2-digits breakdown. Industries, with weights based on 2015 turnover: C - Manufacturing (27 per cent); D - Electricity, gas, steam and air conditioning supply (4 per cent); E - Water supply, sewerage, waste management and remediation activities (1 per cent); F - Construction (5 per cent); G - Wholesale and retail trade, repair of motor vehicles and motorcycles (43 per cent); H - Transportation and storage (5 per cent); I - Accommodation and food service activities (3 per cent); J - ICT (5 per cent); L - Real estate activities (1 per cent); M - Professional, scientific and technical activities (3 per cent); N - Administrative and support service activities (3 per cent).

Table 2: Comparison of the Average Zombie and Non-Zombie Firms

Variable	Unit	Zombie	Non-Zombie
Total Workers	unit	23	15
Turnover	1000 euros	3.168	1.871
Tangible Assets	1000 euros	1.418	546
Intangible Assets	1000 euros	191	136
Firm Age	years	24	22
Labour Prod Deviation	%	-57	19
No. of Observations	-	111.527	662.328

Source: Authors' own computations based on IES.

Notes: In this table, the non-zombie population is restricted to firms older than 10 years in order to allow for a meaningful comparison with the data on zombies (which by definition are older than 10 years). Labor productivity is defined as gross value added per hour worked, Labor Prod deviation as deviation from the sectoral average.

of policy-induced barriers in hampering the exit or restructuring of zombies (extensive margin).

Intensive Margin

Following the specification in Caballero *et al.* (2008) and Adalet McGowan *et al.* (2018), we test whether zombies entail negative spillover effects, e.g. by competing for investment, on viable firms' labour or capital growth. We rely on panel data from 2006 to 2015 to estimate a reduced-form equation on the impact of zombie sectoral congestion on investment and employment growth of the average non-zombie firm in that sector:

$$\begin{aligned}\delta Y_{i,s,t} = \beta_0 + \ & \beta_1 nonzombie_{i,s,t} \\ & + \beta_2 nonzombie_{i,s,t} * RS_{s,t} \\ & + \beta_3 firmcontrols_{i,s,t-1} \\ & + FE_{s,t} + \epsilon_{i,s,t} \quad (1)\end{aligned}$$

where δY denotes capital or employment growth of firm i in a 2-digit industry s in year t, defined as the log difference in tangible assets or in total workers from one year to the other. The dummy *nonzombie* takes the value 1 for non-zombie firms and 0 otherwise. RS is a measure of industry resources sunk in zombie firms, which, depending on the specification, is measured either as KS or LS, taking values between 0 and 1. KS represents the share of tangible assets of zombie firms as a fraction of total tangible assets of all firms in each 2-digit sector. LS denotes the share of total workers employed in zombie firms as a fraction of all workers employed in the sector. Firm controls may include the age of the firm, workers and workers squared (to account for non-linear effects of size) and the turnover growth, as a proxy of growth opportunities. We include interacted two-digit industry-year fixed effects to control for sectoral shocks (as they impact both resources sunk and firm growth) and robust standard errors clustered by industry-year (Adalet McGowan *et al.*, 2018). Firm fixed effects are not suitable in this analytical framework, as zombie status is persistent (Caballero *et al.*, 2008).

The fixed effects structure implies that the absolute effect of resources sunk cannot be estimated, as it is absorbed by the sectoral-year dummy structure. Therefore,

β_2 captures the effect on the average non-zombie in deviation from the effect on zombies. A negative β_2 implies that more resources sunk in zombie firms, representing higher misallocation of capital and labour, adversely affects the *relative* performance of non-zombie firms.

Table 3 presents the estimation results of equation 1 for capital and employment growth. The interaction term is always negative for capital growth, meaning that an increase in resources (capital and labour) sunk in zombie firms is associated with lower investments of the typical healthy firm within a sector. As an illustration, these results mean that the capital growth differential between a non-zombie and a zombie is 0.9 percentage points lower in the textile industry (capital sunk close to 20 per cent) vis-à-vis the consulting sector (capital sunk of around 10 per cent). These findings have implications for aggregate productivity growth given that rising capital misallocation has been found of to be one of the key explanations drivers of the slowdown (Adalet McGowan *et al.*, 2018, Gopinath *et al.*, 2017).

There is, however, no effect on relative employment growth for the average non-zombie. This may reflect the flexibility of capital vis-à-vis labour, as employment is unchanged from one year to the other in more than 50 per cent of the observations (0.4 per cent for the case of capital). These results are consistent with those in Caballero *et al.* (2008). Adalet McGowan *et al.* (2018) find negative spillovers on employment growth, but much smaller than those on investment.

The discussion so far focused on the average firm. Moreover, it is important to understand how zombie prevalence affects the most productive firms within each sector. In Gouveia and Osterhold (2018), we show that the capital stock sunk in non-viable firms is associated with impeded reallocation of resources towards the most productive, both in terms of capital and employment growth.

Extensive Margin

Distorted market competition and resource misallocation can enable a prolonged survival of unviable firms. From a public policy perspective, it is important to understand the role of exit and restructuring barriers in mediating firm dynamics. Well-designed insolvency regimes may promote productivity growth through various channels (Adalet McGowan *et al.*, 2017b). First, by fostering the exit of unviable firms, they promote virtuous market selection, also freeing up resources that are otherwise sunk in zombies. Second, by facilitating the restructuring of viable firms, they spur within-firm growth. Third, they promote firm entry and bolder business projects, by not excessively penalizing failure and by reducing zombie congestion.

To assess the first channel, we develop a differences-in-differences specification à la Rajan and Zingales (1998) that allows us to test for the role of insolvency regimes in mediating exit. Our identification strategy relies on the assumption that industries more exposed to exit and restructuring barriers (the treatment group) are more affected by changes in those policies in comparison with less exposed industries (control group):

Table 3: Zombie Congestion and Capital and Employment Growth (Equation 1)

	(1) dlncapital	(2) dlncapital	(3) dlncapital	(4) dlncapital	(1) dlnemp	(2) dlnemp	(3) dlnemp	(4) dlnemp
nonzombie	0.076***	0.065***	0.066***	0.053***	0.040***	0.031***	0.041***	0.031***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.004)	(0.003)	(0.003)	(0.003)
KS*nonzombie	-0.084***	-0.089***			0.007	0.003		
	(0.022)	(0.022)			(0.014)	(0.012)		
LS*nonzombie			-0.060**	-0.056**			0.005	0.008
			(0.028)	(0.027)			(0.016)	(0.013)
Industry-Year FE	yes	yes	yes	yes	yes	yes	yes	yes
firm-level controls:								
Age and size	yes	yes	yes	yes	yes	yes	yes	yes
Turnover growth	no	yes	no	yes	no	yes	no	yes
Observations	702,667	702,667	702,667	702,667	701,299	701,299	701,299	701,299
Adjusted R^2	0.020	0.036	0.020	0.036	0.067	0.129	0.067	0.129

Source: Authors' own computations.

Note: Standard errors in parentheses. * p < .10, ** p < .05, *** p < .01.

$$Exit_{i,s,t} = \beta_0 + \beta_1 Z_{i,s,t-1} + \beta_2 Z_{i,s,t-1} * Insolvency_{t-1} * Exposure_s + \beta_3 Firmcontrols_{i,s,t-1} + FE_{s,t} + \epsilon_{i,s,t} \quad (2)$$

where $Exit$ is a dummy variable, indicating whether a firm i exits ($Exit = 1$) or stays in the market ($Exit = 0$) in year t.[15] The variable $Insolvency$ denotes a measure of the height of barriers to exit imposed by the insolvency regime in year t and $Exposure$ is measured by the natural turnover rate of each 2-digit industry s (see Section 3.2 for details). The dummy Z takes the value 1 for zombie firms, 0 otherwise. Firm controls may include age, number of workers and number of workers squared, firm turnover growth, and relative labour productivity vis-à-vis the sectoral-year average. Two digits sectoral-year fixed effects are included, and robust standard errors are clustered at the sectoral-year level. A negative, β_2 implies that lower barriers to exit increase the exit rate of zombie vis-à-vis non-zombies in sectors more exposed to those barriers, contributing to an improved resource allocation.

Table 4 presents the results for the exit regression (equation 2), where we indeed find a negative coefficient for β_2, but only when considering a lag of two periods for the insolvency framework. This is not surprising as exit procedures take time to be finalized (and our dependent variable captures the moment when the firm actually exits from the market). To illustrate these results, take the administrative and support services sector, with one of the highest exposures to exit barriers, and the machinery and equipment production industry, one of the least exposed. The reforms introduced since 2012 increase the exit rate differential between zombies and non-zombies by 1.8pp in the most exposed

15 Ideally, one would like to focus on firms that exited due to insolvency procedures and not on all firms that exited the market (for instance, because they merged with another firm). However, we do not have access to a reliable source on the reason for exit.

industry in comparison with the least exposed one. Comparing industries with an exposure differential equivalent to the percentiles 75-25, the increase in the exit rate differential is 0.4pp.

As the $Exit$ dummy is a proxy for the start of the exit procedures, we re-estimate our model with different leads of the dependent variable (e.g. $Exit = 1$ if the firm is no longer in the database in $t + 2$), with no qualitative changes to the results.

Effective insolvency regimes should foster not only the exit of non-viable firms but, according to the second channel presented above, also promote the restructuring of the most productive zombies, where feasible.

To test whether lower exit and restructuring barriers in a certain sector foster the exit of the least productive and the restructuring of the most productive zombies, we again apply a differences-in-differences specification:

$$R_{i,s,t} = \beta_0 + \beta_1 LPdev_{i,s,t-1} + \beta_2 LPdev_{i,s,t-1} * Insolvency_{t-1} * Exposure_s + \beta_3 Firmcontrols_{i,s,t-1} + FE_{s,t} + \epsilon_{i,s,t} \quad (3)$$

where R takes the value 1 if a zombie firm in $t - 1$ turns non-zombie in t and stays healthy the period after ($ICR > 1$). $LPdev$ is the per cent deviation of the firm labour productivity in relation to the sectoral-year average. The variable $Insolvency$ denotes a measure of the height of barriers to exit imposed by the insolvency regime in year t and $Exposure$ is measured by the natural turnover rate of each 2-digit industry s (see Section 3.2). Firm-level controls include age, number of workers and number of workers squared and turnover growth. As before, two digits sectoral-year fixed effects are included and robust standard errors are clustered at the sectoral-year level. A negative β_2 implies that lower exit and restructuring barriers promote the restructuring of the most productive zombies in sectors relatively more exposed to those barriers.

Conversely, from the population of zombies, we would expect the least productive firm within each sector to have a higher likelihood of leaving and effective insolvency regimes to foster this positive selection. We thus re-estimate equation 3 with a dummy that takes the value 1 if the zombie leaves the market as the dependent variable. A positive β_2 implies that lower exit and restructuring barriers improve the efficient resource allocation, by strengthening the relationship between lower productivity and higher probability of exit in sectors relatively more exposed to the barriers.

In Table 5, we provide evidence that lower exit and restructuring barriers promote the restructuring of the most productive in sectors relatively more exposed to the policy change, but we fail to find a significant effect for the exit margin (although

Table 4: Exit Rates and Exit Barriers (Equation 2)

	(1) exit	(2) exit	(3) exit	(4) exit	(5) exit	(6) exit	(7) exit	(8) exit
L2.Zombie	0.055***	0.053***	0.054***	0.053***	0.053***	0.051***	0.053***	0.051***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
L2.ZombieXInsolvency XExposureUK	-0.002**		-0.002**		-0.002**		-0.002**	
	0.001		0.001		0.001		0.001	
L2.ZombieXInsolvency XExposureUS		-0.002**		-0.002**		-0.002**		-0.002**
		(0.001)		(0.001)		(0.001)		(0.001)
Industry-Year FE	yes	yes	yes	yes	yes	yes	yes	yes
firm-level controls:								
Age and size	yes	yes	yes	yes	yes	yes	yes	yes
Turnover growth	no	no	yes	yes	no	no	yes	yes
Labour productivity	no	no	no	no	yes	yes	yes	yes
Observations	416,622	415,437	416,622	415,437	396,753	395,717	396,753	395,717
Adjusted R^2	0.013	0.013	0.013	0.013	0.014	0.014	0.014	0.014

Source: Authors' own computations.

Note: Standard errors in parentheses. * p < .10, ** p < .05, *** p < .01.

Table 5: Zombie Dynamics - Exit and Restructuring (Equation 3)

	(1) restructure	(2) restructure	(3) restructure	(4) restructure	(5) exit	(6) exit	(7) exit	(8) exit
L.LabourProd	0.055***	0.054***	0.056***	0.054***	-0.031***	-0.028**	-0.031***	-0.028**
	(0.016)	(0.019)	(0.017)	(0.019)	(0.011)	(0.012)	(0.011)	(0.012)
L.LabourprodXInsolvency XExposureUK	-0.004**		-0.004**		0.002		0.002	
	(0.002)		(0.002)		(0.001)		(0.001)	
L.LaborprodXInsolvency XExposureUS		-0.005**		-0.005**		0.001		0.002
		(0.003)		(0.003)		(0.002)		(0.002)
Industry-Year FE	yes	yes	yes	yes	yes	yes	yes	yes
firm-level controls:								
Age and size	yes	yes	yes	yes	yes	yes	yes	yes
Turnover growth	no	no	yes	yes	no	no	yes	yes
Observations	32,499	32,415	32,499	32,415	33,299	33,222	33,299	33,222
Adjusted R^2	0.019	0.019	0.019	0.019	0.011	0.011	0.011	0.011

Source: Authors' own computations.

Note: Standard errors in parentheses. * p < .10, ** p < .05, *** p < .01.

the sign is the expected one).[16] Again, as an illustration, the results indicate that the reforms introduced since 2012 increase the likelihood of restructuring of a zombie firm 10 per cent more productive than the average in the sector by 0.4pp when comparing the administrative sector, with one of the highest exposures to exit and restructuring barriers, and the machinery and equipment production industry, one of the least

16 The significant effect on restructuring is present already with only one lag of the policy variable, whereas in equation 3 two lags are needed. This may reflect the different nature of exit and restructuring procedures, with the former taking more time than the latter. In any case, we do not find a significant effect of lowering exit barriers on fostering the exit of the least productive zombies within each sector, even when using lags higher than 1. This may relate to the limitations of our exit variable, which may wrongly classify a M&A as an exit. The lack of significance of the coefficient may also be due to the reduced sample size, by considering only the population of zombies and comparing those with different productivity levels within each sector. Using the sub-components of the insolvency indicator does not change the results. This is expected, given the high interrelation among the different sub-policy areas.

exposed.

Finally, we provide preliminary evidence on entry dynamics. Accounting for the entry channel is particularly challenging, given that it is not possible to estimate the pool of potential entrants. Therefore, we focus on two predictions, one on the quality of the entrants and another on their quantity.

We start by testing whether there is evidence that higher zombie congestion increases the threshold of productivity that a new entrant must surpass, given that zombies increase market wages, reduce market prices and reduce the market share for non-zombies (Caballero *et al.*, 2008). We find that the sectoral mean productivity of new entrants (deviation towards sectoral mean) is positively correlated with the presence of zombies in the sector, measured by sunk capital (controlling for industry and/or time fixed effects; when controlling for sectoral turnover growth the effects become not significant). We do not find an effect for sunk labour.

Lastly, we check whether sectoral entry is hampered by zombie congestion, given the increased productivity threshold and the crowding-out of capital and labour. To do so, we compute the correlation between measures of zombie congestion and sectoral yearly entry rates. As in Schivardi *et al.* (2017), we fail to find any significant results for sunk labour and capital, as well as when controlling for sectoral turnover growth (to control for growth opportunities). However, we do find a negative correlation with the share of zombies in the sector, meaning that industries with a higher number of zombie players display lower entry rates.

Conclusion

There is widespread evidence of resource misallocation across OECD countries harming productivity growth. By making use of a comprehensive set of firm-level data for Portugal, we contribute to the literature on the role of zombie firms in explaining resource misallocation, by reinforcing the evidence on spillovers (intensive margin) and by providing novel evidence on the exit and restructuring channels (extensive margin).

Portugal is a rich case study, as it is one of the OECD countries with the largest drop in exit and restructuring barriers in recent years. It is thus particularly suited for an assessment of the extensive margin effects. Furthermore, given the severity of the crisis that hit the country during the period studied, this research brings additional insights into the literature on zombies' spillovers. While during deep recessions, the opportunity costs of sunk resources are lower, given the limited outside opportunities for reallocation, it is also the time where capital is scarcer and thus where crowding out effects could be stronger. The balance of the two opposing forces is determinant for the outcome. Moreover, by relying on an administrative database covering all Portuguese firms, we improve on the robustness of studies that rely on specific types of firms (e.g. listed firms) or datasets with limited coverage (e.g. covering only larger firms or sectors). The results of this research for Portugal are relevant for other countries that face a rising presence of zombie firms and high policy-induced structural barriers to foster resource allocation and promote a more effective exit channel.

Overall, we confirm the results in the literature on the high prevalence of zombie firms, being significantly less productive than their healthy counterparts and thus dragging aggregate productivity down. Furthermore, while we find evidence of positive selection within zombies, with the most productive restructuring and the least productive exiting, we also show that the zombies' productivity threshold for exit is much lower than that of non-zombies, allowing them to stay in the market, distorting competition and accounting for a sizable share of existing resources. This curbs the growth of viable firms, harming a more efficient intra-sectoral resource reallocation. We show that a reduction in exit and restructuring barriers promotes a more effective exit channel, disproportionately fostering the exit of non-viable firms, and stimulate the restructuring of the most productive zombies. These results highlight the role of public policy in addressing zombies' presence and thus in promoting productivity growth.

While fostering the exit of the least productive is appealing, one needs to consider the broad implications carefully. In some sectors, zombies employ more than one out of five workers, making zombies responsible for a significant share of employment. Thus, the policy mix must be carefully designed to address and minimize social costs that may arise. This may be particularly important at the regional level.

The reallocation of employment is not only crucial from a social perspective, but it is also determinant for positive potential output effects, as otherwise, the stock of human capital is merely reduced. Therefore, a flexible education system and effective Active Labor Market Policies have a particular role to play (Andrews and Saia, 2017). Going forward, it would be important to understand better the employment dynamics, both in terms of type of contract (permanent versus temporary versus contract work) and level of skills to better inform policymakers.

The same concern holds for capital: in some industries, more than 25 per cent of the sectoral fixed capital is accounted for by zombies. In case they exit the market, can the stock of capital be reallocated to more productive uses? While there is some sectoral evidence that at least part of the stock of capital can be reassigned (see, for example, Australian Productivity Commission, 2015), one can expect a part of this stock to be lost, as it is firm-specific. On improving the allocation of capital flows, there are important complementarities between bank health and good insolvency regimes, as the latter reduce the incentives for evergreening and bank forbearance. In any case, it should be noted that zombies, on average, have more tangible assets to pledge as collateral. If banks' financing criteria focus on the existence of collateral, rather than on the quality of the project or the firm, zombie lending lasts even without evergreening motives.

There is again a role for policy action, in particular as non-collateralizable assets (the intangibles) gain weight in the economy. Public policy may be vital in correcting the asymmetries of information existing in the bank financing market, for instance via well-designed public guarantees systems (Rodrigues *et al.*, 2016; Farinha and Félix, 2015), and in fostering the development of alternative financing options, in particular in the context of supranational initiatives, such as the so-called Capital Markets Union in the EU. Future research could provide evidence on the effects of zombies separately on tangible and intangible investment, as our preliminary evidence suggests that the effect is asymmetric.

Effective policy action hinges on a deeper understanding of the nature of zombie firms and how they interact with existing institutional features. Are these zombies inherently unviable, or do they become zombies ex-post due to bad shocks or due to a regulatory setting? While there is evidence that ex-ante heterogeneity across firms is a key determinant of ex-post growth (e.g. Pugsley *et al.*, 2017), it is vital to understand better what those ex-ante factors are and what drives zombie dynamics. Moreover, in particular as the margin of improvement in exit and restructuring barriers decreases, one needs to explore ways to further foster the exit of zombies, the growth of viable incumbents and the entry of dynamic firms (e.g. Haltiwanger *et al.*, 2013). For instance, ensuring a fit for purpose regulatory environment is an important challenge for policymakers, as product market distortions and administrative barriers to entry are also positively associated with higher zombie congestion and lower exit (Adalet McGowan *et al.*, 2017a/b; Monteiro *et al.*, 2017; Aghion *et al.*, 2017).

Concerning aggregate dynamics, while zombie congestion and intra-sectoral reallocation are (increasingly) important, other dynamics concur to explain the productivity slowdown. On top of the more classical discussions on cross-sectoral misallocation, there are also changing dynamics at the other end of the zombie productivity spectrum, i.e. the very high growth firms (the so-called gazelles). They are not only becoming rarer but also less productive (e.g. Pugsley *et al.*, 2017). To different degrees, all these elements, taken together, explain country-level developments. A successful policy agenda must tackle these challenges in a coherent and encompassing manner.

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Transatlantic Technologies: The Role of ICT in the Evolution of U.S. and European Productivity Growth

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Abstract

We examine the role of the ICT revolution in driving productivity growth behavior for the United States and an aggregate of ten Western European nations (the EU-10) from 1977 to 2015. We find that the standard growth accounting approach is deficient when it separates sources of growth between ICT capital deepening and TFP growth, because much of the effect of the ICT revolution was channeled through spillovers to TFP growth rather than being limited to the capital deepening pathway. Using industry-level data from EU KLEMS, we find that most of the 1995-2005 U.S. productivity growth revival was driven by ICT-intensive industries producing market services and computer hardware. In contrast the EU-10 experienced a 1995-2005 growth slowdown due to a paucity of ICT investment, a failure to capture the efficiency benefits of ICT, and performance shortfalls in specific industries including ICT production, finance-insurance, retail-wholesale, and agriculture. After 2005 both the United States and the EU-10 suffered a growth slowdown, indicating that the benefits of the ICT revolution were temporary rather than providing a new permanent era of faster productivity growth.

Introduction

After a long slump between the 1970s and mid-1990s, when the annual rate of productivity growth in the United States languished, a distinct productivity growth revival occurred during the subsequent decade of 1995-2005. But that episode of

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renewed growth did not last, as in the subsequent decade of 2005-15 U.S. productivity growth slumped back to a rate even slower than that which had occurred prior to 1995. The trajectory of growth in Western Europe was quite different, starting off with a pre-1995 productivity growth rate faster than in the United States but then slumping in two stages, after 1995 and again after 2005, to a pace even slower than the mediocre post-2005 pace achieved by the United States.

During the half decade between 1995 and 2000, the United States experienced a pronounced surge of investment in information and communication technology (ICT) equipment and software. The year 1995 marked the initial appearance of widely used web browsers, and the late 1990s witnessed an investment boom in hardware and software as business firms rushed to modify their business methods to take advantage of the newly invented internet and new business services such as Google, founded in 1998. Several articles published soon after this ICT investment boom credited it for most or all of the post-1995 revival in U.S. productivity growth (Jorgenson and Stiroh (2000), Oliner and Sichel (2000), and Stiroh (2002)).

However, the evolution of the United States data since the year 2000 raises a set of questions about the causal role of ICT. Since productivity growth continued to be strong from 2000 to 2005 yet ICT investment slumped after 2000, does ICT investment still play a causal role in explaining the productivity growth revival when the growth interval is extended? Furthermore, since U.S productivity growth slumped after 2005 to a rate lower than that before 1995, to what extent does lower ICT investment explain that post-2005 stalling of the growth process?

The failure of Europe to enjoy a productivity growth revival similar to the United States after 1995 and its lamentably slow performance after 2005 raises further questions about the role of ICT investment. Did the absence of a post-1995 growth revival occur because Europe invested substantially less in ICT equipment than did the United States? Or was it that the extent of ICT investment in Europe was similar to the United States but that same level of investment had a smaller payoff than in the United States? Given that the United States and Europe have similarly slow productivity growth rates after 2005, why was that growth performance so poor? To what extent did the same ICT-intensive industries that led the post-1995 industries also contribute to the post-2005 decline in growth?

The most common way of answering these questions is to conduct an exercise in growth accounting, crediting ICT and non-ICT capital growth as two distinct sources of growth by multiplying their growth rates by their income shares. A complementary approach is to use industry data to reveal the extent to which individual industries that produce ICT equipment or are relatively intensive users of ICT equipment account for periods of rapid or slow aggregate productivity growth. This article uses both approaches to investigate the role of ICT investment in the post-1995 and post-2005 behavior of growth in labour productivity and in total factor productivity (TFP) in the United States and in Western Europe.

Using KLEMS data on individual industries as in our previous transatlantic study (Gordon and Sayed, 2019), we have developed time series for a group of 10 Western European nations, which we call the "EU-10".[2] These data allow a comparison between the EU-10 and the United States for 16 industrial sectors as well as 11 subindustries within manufacturing. The creation of data for the EU-10 as a single European aggregate contrasts with previous studies that tend to examine a dizzying array of data for numerous individual European nations. The EU-10 aggregation greatly facilitates the task of isolating sources of differences in growth behavior between the United States and Europe. In our previous study in this journal (Gordon and Sayed, 2019) we divided up the sources of labour productivity growth for the 27 industries among capital deepening, changes in labour composition, and growth of TFP. There we highlighted individual industries that had performed particularly well or badly and examined the different time paths of capital deepening and TFP on each side of the Atlantic.

This study goes further by examining the role of ICT capital as a source of differences in labour productivity and TFP growth between the United States and EU-10 over three time periods extending from 1977 to 2015 and divided at 1995 and 2005.[3] We start by studying the evolution of labour productivity growth over the three time periods for the total economy and for two dimensions of disaggregation – industries producing commodities versus services, and industries that are relatively intensive or non-intensive users or producers of ICT equipment and software. We emphasize the distinction between industries producing commodities vs. services, since the usual explanation of the role of ICT intensiveness in the productivity growth process emphasizes the role of ICT in revolutionizing office spaces as workers transitioned to desks with web-enabled personal computers, firms shifted their businesses to online platforms, and communication and collaboration occurred through the internet.

We then conduct a regression analysis to quantify the role of ICT intensiveness as a source of changes in productivity growth after 1995 and after 2005. We disentangle the relative roles of the *amount* of ICT intensiveness versus the *payoff* from a given extent of ICT intensiveness as sources of Europe's failure to experience a post-1995 productivity growth revival and as sources of the post-2005 slowdown on both sides of the Atlantic. We then ask whether ICT intensity contributed to productivity growth purely through its effect on capital deepening or, whether in addition ICT intensiveness spilled over to boost the growth of TFP.

We find that additional productivity

2 "Western Europe" consists of the fifteen members of the European Union prior to its 2004 enlargement. Ten of these nations are included in our EU-10 data – Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, and the United Kingdom. The five nations that are excluded – Finland, Greece, Ireland, Luxembourg, and Portugal – are all small and together account for only 7 per cent of 2017 EU-15 GDP (Source: Conference Board Total Economy Database).

3 This study starts in 1977 because that is the initial year of our ICT data. The previous article extended back to 1972 for the EU-10 and to 1950 for the United States.

growth in ICT intensive industries drove almost all of the post-1995 revival in U.S. productivity growth. However, this change in growth occurred almost entirely in services-producing industries rather than commodities-producing industries except for the electric machinery industry that produces computer hardware. This makes sense because the most intensive users of ICT were industries in the services sector. The EU-10 story is quite different. Productivity growth in producing computer hardware in the EU-10 actually slowed after 1995 in contrast to its explosive growth in the United States. Further in the EU-10 there was little difference between the productivity growth slowdown after 1995 and after 2005 in industries that were intensive in ICT use versus the non-ICT industries. Europe not only invested less in ICT hardware but failed to reap its benefits even in industries that were heavy ICT users.

Plan of the Article

The article has six main sections. The first section begins with an overview of the literature on the relationship between ICT and productivity growth in the United States and Europe. Part 2 starts with a contrast of productivity growth rates over the three periods for the United States and EU-10. We present a decomposition of sources of growth that emphasizes the distinction between TFP growth and ICT capital deepening. In part 3 we introduce and display indicators of ICT intensity and examine the behavior of productivity growth in the ICT-intensive and ICT non-intensive industries. Part 4 provides the analytical framework for the regression analysis in which the observations are the evolution of labour productivity and TFP growth over the three periods for 27 industries. Part 5 carries out the regression analysis, emphasizes the similarity of results explaining growth in labour productivity versus TFP, distinguishes between the role of differing ICT intensity versus the payoff from ICT, and singles out individual industries as primarily responsible for the results. Part 6 summarizes the results and concludes.

Overview of the Related Literature

Initial analyses of the U.S. experience of a productivity growth revival emerged initially in the early-to-mid 2000s. Oliner and Sichel (2000) utilize a simple Solow-style growth-accounting framework that divides nonfarm business productivity growth into the contributions of labour, ICT-capital, non-ICT capital, and TFP. After 1995, they find significant jumps in ICT capital and TFP that explain the entire acceleration in labour productivity growth between 1991-95 and 1996-99; non-ICT capital deepening takes a back seat. They suggest that about half of this acceleration was due to investment in ICT capital, one-fourth due to TFP growth in computer production and related industries, and the rest due to TFP growth in other sectors. Hence, they conclude that the contributions of investment in information and communications technology appear to be the main drivers of productivity growth.

TFP takes a slightly more central role in the analysis of Jorgenson and Stiroh (2000). They attribute the acceleration between 1990-95 and 1995-98 in labour productivity growth roughly equally between TFP and capital deepening, with about two thirds of the increase in TFP due to non-ICT producing industries. They explicitly suggest inter-industry spillover effects, with the higher TFP growth of ICT-producing industries paving the way for other industries like wholesale and retail trade to invest in computers and electronic equipment.

Stiroh (2002) employs industry-level BEA data for 1977-2000 to examine the industry composition of growth prior to and after 1995. Stiroh flags a subset of his industries as ICT-intensive and examines the differential effect of ICT intensity on the post-1995 productivity growth acceleration. He estimates that ICT-intensive industries experienced a productivity growth revival of roughly 2 percentage points while non-ICT intensive industries experienced no revival, suggesting that the post-1995 productivity growth revival was *entirely* driven by industries that invested heavily in ICT. His emphasis on the stimulative role of these ICT-using industries shows that the productivity acceleration was not driven just by those industries producing computer hardware and software.

Jorgenson, Ho, and Stiroh (2005) emphasize similar spillover effects. These authors find that TFP accelerations of the late 1990s and early 2000s required investments in ICT capital. Thus ICT capital deepening *augments* TFP growth. A subsequent article by the same authors (2008) distinguish between productivity growth from 1995-2000 that was driven by ICT-*producing* industries, as contrasted to the 2000-2005 interval that was driven by industries intensive in ICT *use.* They also point to the positive effects of structural market changes, such as reallocation effects, increases in competition, and the emergence of flexible labour markets. Bartelsman *et al.* (2007) suggest that while a productivity acceleration was led by the technology and wholesale/retail sectors in the late 1990s, additional growth in the finance and business services sectors during the early 2000s sustained an aggregate acceleration in growth until 2004, with TFP playing the primary role.

While there is a broad consensus that ICT-intensive industries drove the acceleration of U.S productivity growth in the late 1990s, the subsequent turnaround to much slower productivity growth after 2005 raises new questions. Did the ICT revolution of the late 1990s have a sustained positive impact on productivity growth, or was it only a one-time shock? In Fernald's (2015) interpretation, the ICT revolution had a temporary "level effect" that resulted in a marked but short-lived period of additional productivity growth that ran its course after about a decade. Extending Stiroh's (2002) result, Fernald suggests that both the rise and fall of labour productivity growth resulted from a temporary boost to productivity growth in both ICT-producing and ICT-using industries. Cette *et al.* (2016) likewise claim that the ICT revolution had run its course by 2004. In their view, the ability of ICT investment to foster TFP growth through channels like electronic inventory management or role-reorganization in services industries was exhausted by 2004-2005.

Byrne *et al.* (2016) maintain that while ICT-innovations continued into the late-2000s, they were not potent enough to prevent a broad post-2004 slowdown in U.S. productivity growth. They also suggest that the subsequent post-2005 wave of communications innovation associated with smartphones and social networks has enhanced consumer surplus without appreciably raising business-sector productivity. On the other hand, Byrne and Corrado (2017) suggest that ICT price indices have been mis-measured, with falls in the price level of ICT equipment understated by about 5.9 percentage points every year between 2008-14. As a result of this price mismeasurement, ICT services sector may have actually been contributing about 1.4 points to total economy productivity growth after 2014. About a quarter of this 1.4 points is concentrated in investment in cloud-based computing and online services, the use of which has been steadily rising in the economy through the late 2010s.

The dominant role of ICT investment in the U.S. productivity growth acceleration of the late 1990s is not universally accepted. Acemoglu *et al.* (2014) in a study of U.S. manufacturing show little difference in the degree of growth resurgence between ICT-using and non-ICT-using industries. While these authors do find a positive impact on labour productivity for manufacturing industries that utilize high-tech equipment, they cast doubt on the proposition that ICT intensity can explain the entire post-1995 revival. In our subsequent study of productivity growth differences across industries, we are careful to distinguish between the quite different behavior of industries producing commodities (including manufacturing) from those producing services.

In an early comparative study of ICT-related investment, Colecchia and Schreyer (2002) show that nine OECD countries ramped up investment in ICT in the 1990s.[4] In the late 1990s, ICT investment contributed between 0.3 and 0.9 percentage points to economic growth, although the United States benefited much more than any of the other countries in their data set. In contrasting the U.S. mid-90s acceleration with the deceleration in Europe, O'Mahony *et al.* (2008) survey a variety of causes, including lower total factor productivity (TFP) growth and the smaller importance of ICT-producing industries in Europe. They attribute the absence of a post-1995 productivity growth revival in Europe to the slower emergence of a knowledge economy in Europe, particularly in the services sector, and argue that particular labour market structures and regulatory laws may have played a role in dampening productivity growth.

Timmer and van Ark (2005) describe how Europe lagged behind the United States in ICT investment after 1980, implying that the region was not as prepared as the United States to reap the benefits of the post-1995 ICT revolution. TFP gains from ICT-producing sectors and additional capital deepening from ICT-capital investment explain almost all the U.S.-Europe productivity differential during 1995-2001. Their framework uses a European Union aggregate with a growth decomposition of labour productivity into its components of capital

4 Australia, Canada, Finland, France, Germany, Italy, Japan, the U.K., and the United States.

deepening, labour quality, and TFP.

Some authors have argued that Europe simply needed to play catch up to the U.S again, as it had done in the early postwar years. For example, Inklaar *et al.* (2007) argue that the main differences between U.S. and EU growth were due to a shortfall in TFP growth in the European services sector, and that over the next few years following their 2007 publication date we would see increased ICT investment and a subsequent growth revival in the European economy. But as we have seen, that growth revival did not occur. In fact, Dabla-Norris *et al.* (2015) argue that while the services sector drove the gap between U.S. and European productivity growth, the time to tap into the full potential of ICT may have already passed for Europe. Cette *et al.* (2016) argue that the United States established a technological frontier to which Southern European countries like Italy and Spain needed to catch up. But this explanation fails to explain the lack of an ICT-driven growth revival in the EU countries outside of Southern Europe.

Inklaar *et al.* (2011) suggest that the significant decline in European labour force participation and hours worked per person between 1973 and 1995 may have meant that, when the ICT revolution finally came, European industries may not have been ready to reap the benefits of new technologies. Bloom *et al.* (2012) show that United States-owned multinational companies that had operations in Europe were able to reap the benefits of the ICT revolution while European firms were not, suggesting that differences in management structure between the two regions may have helped drive this transatlantic productivity gap. Adding further evidence of the reorganization role of ICT investment in the United States resurgence. Castellani *et al.* (2016) find that European countries performed worse at both investing in research and development and in transforming that R&D expenditure into a significant productivity growth response. Moreover, these authors contend that while the United States shifted its economy to "high-tech" sectors, much of the European economy remained in "medium-tech" and "low-tech" sectors, where capital deepening is the main channel driving productivity growth.

Transatlantic Productivity Growth, 1977-2015

We begin with a straightforward comparison between the United States and EU-10 in the growth rate of labour productivity during three periods spanning 1977 to 2015. Data limitations require that 1977 is the starting date in this article, as contrasted with 1972 for the EU-10 and 1948 for the United States in our previous study (Gordon and Sayed, 2019).[5] After the initial labour productivity growth comparison, we proceed to a Solow-type decomposition of the sources of growth, including ICT and non-ICT capital deepening, changes in labour composition, and

5 Our KLEMS data are missing observations on several inputs including ICT capital for the "Professional and Administrative" industry prior to 1977. This data gap requires that we start this study in 1977 rather than in 1972, the starting data of our data for the EU-10.

Table 1: Labour Productivity Growth in the United States and EU-10 (Average Annual Rate of Change)

	United States			EU-10		
	1977-1995	1995-2005	2005-2015	1977-1995	1995-2005	2005-2015
Total Economy	1.11	2.17	0.87	2.21	1.26	0.63
Market Economy	1.54	2.89	0.86	2.41	1.61	0.72
Commodities	2.12	3.59	1.29	3.22	2.19	0.85
Market Services	1.41	2.61	0.65	1.71	1.21	0.63

Source: All cells are computed from the merged KLEMS database as described in the Data Appendix of Gordon and Sayed (2019).

changes in TFP growth.

Productivity Growth Across Time for the Major Sectors

We look first at growth rates of labour productivity in Table 1, where the first two rows cover the total economy and the market economy (which excludes public services, education, health, and real estate). The bottom two lines divide up the market economy into industries producing commodities (agriculture, mining, manufacturing, construction, and utilities) and the remaining industries producing market services.

The top row of Table 1 for the total economy contrasts the 1995-2005 revival of U.S. productivity growth from 1.11 to 2.17 per cent per year with the post-1995 slowdown of EU-10 growth from 2.21 to 1.26 per cent per year. Both entities share in common a post-2005 growth slowdown, from 2.17 to 0.87 per cent per year for the United States and from 1.26 to 0.63 per cent per year for the EU-10. The second line for the market economy shows a sharper 1.11 per cent post-1995 increase in U.S. growth as compared to a smaller 1.06 per cent post-1995 increase for the total economy. The U.S. market economy also exhibits a more pronounced post-2005 slowdown of 2.03 per cent per year as contrasted to the slowdown of 1.30 per cent per year for the total economy. The greater post-1995 revival and post-2005 slowdown in the market economy than the total economy reflects the relative stagnation of growth during all three periods in the four industries within the non-market economy. There are smaller differences between the total and market economies for the EU-10, where the overall slowdown from the first to the third period is 1.58 per cent per year for the total economy and a similar 1.69 per cent for the market economy.

The bottom two rows of Table 1 divide up the market economy into commodities-producing and services-producing industries and show that productivity growth has been faster in all three periods on both sides of the Atlantic in the production of commodities than in the production of services. In the United States, the post-1995 growth revival and post-2005 growth slowdown were of roughly the same order of magnitude in commodities as in services, as the margin by which commodities growth exceeded services growth was relatively stable across the three periods (0.71, 0.98, and 0.64 percentage points respectively). From the first to last period the growth slowdown in commodities of 0.83 percentage points was almost the same as the 0.76 percentage points slowdown in services.

The story for commodities versus services in the EU-10 is different, as the margin by which commodities growth exceeded services growth shrank from 1.51 percentage points in the first period to a mere 0.22 percentage points in the last period. The extent of the early-to-late productivity growth slowdown was 2.37 percentage points for commodities and a smaller 1.08 per cent for services. Thus in studying the behavior at the industry level we can anticipate finding that the problem of diminished growth in the EU-10 is disproportionately an issue of performance in the commodities sector, whereas in the United States responsibility for the post-1995 revival and post-2005 slowdown is shared roughly equally between commodities and services.

Was productivity growth in the EU-10 held back because its industry mix reflected a smaller role for hi-tech industries and a larger role for low-tech industries? This suggestion can be tested by calculating an alternative aggregate EU-10 productivity growth rate when the U.S. industry mix is applied to the EU growth rate of productivity in each industry. We multiply each European industry's labour productivity growth rate by the U.S. value-added share of that industry for each year from 1977 through 2015 and then sum up the industry terms to calculate a hypothetical counterfactual aggregate for EU-10 labour productivity growth. We find that, were the EU-10 to have shared the same industry composition as the United States, its alternative aggregate productivity growth would have been 1.69 per cent for 1977-95, 1.28 for 1995-05, and 0.76 for 2005-15.

Compared with the actual growth rates of 2.21, 1.26, and 0.63 for the same time periods, we see that the U.S. industry mix substantially *lowers* EU productivity growth in the first period, makes no difference in the second period, and slightly raises growth in the third period. The big change in the 1977-95 period occurs because the United States had a substantially lower share of total output devoted to commodities production, and since EU commodity growth was almost double growth in the services sector, imposing United States share weights reduces counterfactual EU 1977-95 growth. The counterfactual early-to-late slowdown for the EU is reduced from 1.58 percentage points in the actual data to 0.93 points in the counterfactual experiment which imposes U.S. weights. This exercise is another way of drawing attention to the predominant role of the commodities sector in driving the early-to-late slowdown in EU-10 productivity growth.

Sources of Growth Decomposition

Now we take the productivity growth rates from Table 1 and apply a standard decomposition of sources of growth in Table 2. The U.S. decomposition appears in the left half of the table and the EU-10 version in the right half. The growth rate of labour productivity ("LP") from Table 1 is listed in the left column and is decomposed in the remaining columns into the contributions of TFP, changes in labour quality ("LQ"), ICT capital deepening ("ICT KD") and non-ICT capital deepening ("NICT KD"). Here we ignore the LQ column, as the numbers are small and vary little across time

Table 2: U.S. vs EU-10 Labour Productivity (LP) Growth Decomposition into Contributions of Total Factor Productivity (TFP), Labour Quality (LQ), ICT Capital Deepening (ICT KD), and non-ICT Capital Deepening (NICT KD), 1977-2015 (Per Cent or Percentage Point Change per Year)

	United States					EU-10				
	LP	TFP	LQ	ICTKD	NICTKD	LP	TFP	LQ	ICTKD	NICTKD
Total Economy										
1977-1995	1.11	0.53	0.17	0.19	0.22	2.21	0.83	0.14	0.31	0.93
1995-2005	2.17	0.77	0.22	0.51	0.66	1.26	0.27	0.29	0.30	0.40
2005-2015	0.87	0.57	0.19	0.17	-0.06	0.63	-0.02	0.19	0.13	0.33
Market Industries										
1977-1995	1.54	0.59	0.19	0.46	0.31	2.41	1.18	-0.04	0.25	1.02
1995-2005	2.89	1.46	0.25	0.80	0.38	1.61	0.48	0.30	0.37	0.47
2005-2015	0.86	-0.17	0.18	0.25	0.60	0.72	0.02	0.19	0.18	0.34
Commodities										
1977-1995	2.12	1.34	0.29	0.30	0.20	3.22	1.70	-0.18	0.23	1.48
1995-2005	3.59	2.57	0.30	0.20	0.52	2.19	1.01	0.11	0.22	0.85
2005-2015	1.29	-0.20	0.24	0.06	1.19	0.85	-0.08	0.05	0.12	0.76
Market Services										
1977-1995	1.41	0.22	0.13	0.63	0.44	1.71	0.31	0.25	0.41	0.75
1995-2005	2.61	0.89	0.26	1.23	0.24	1.21	0.08	0.41	0.43	0.29
2005-2015	0.65	-0.11	0.21	0.31	0.25	0.63	0.04	0.26	0.19	0.14

Source: EU-10 data and U.S. labour productivity and labour quality data are from the KLEMS Database. Real ICT and non-ICT capital deepening series for the United States are backcast by deflating nominal KLEMS investment data by weighting price deflators in BEA NIPA Table 5.3.4 with nominal investment values in Table 5.3.5. ICT investment is deflated using rows 10, 17, and 18, with non-ICT investment using the remaining rows. U.S. TFP is subsequently calculated as a residual.

intervals.

The question addressed by this exercise is the extent to which the rise and fall of U.S. productivity growth, as well as the two-phase decline in EU productivity growth, were associated with changes in TFP as contrasted with ICT and non-ICT capital deepening. In the top left row for the U.S. total economy, only a small portion of the post-1995 LP growth acceleration of 1.06 percentage points is due to the contribution of TFP (0.24 points), and much more to the two components of capital deepening (ICT 0.32 points and non-ICT 0.44 points). The story is similar for the 1.30 point productivity slowdown after 2005, with a minor TFP contribution of 0.20 points contrasted with ICT and non-ICT capital deepening contributions of 0.34 and 0.72 points, respectively. Stated another way, the contribution of ICT capital deepening accounted for less than one-third of either the post-1995 or post-2005 changes in U.S. labour productivity growth.

Moving down to the next U.S. sector describing the market economy the up and down movement of productivity growth is greater (1.35 and -2.03 points), and the contribution to these movements of TFP growth is considerably larger than for the total economy. The contribution of non-ICT capital deepening is negligible for post-1995 and goes in the wrong direction as an explanation for the post-2005 productivity growth slowdown. But we still retain the finding that less than one-third of the overall change can be attributed to ICT capital deepening (0.34 and -0.55 points respectively). Thus our initial look at the U.S. economy appears to contradict the finding in much of the literature reviewed above that the post-1995 acceleration of U.S. productivity growth was primarily driven by ICT investment.

The next sections for the United States provide the growth decomposition for commodities-producing industries and for market services. In commodities, a 1.23 point post-1995 acceleration in TFP growth explains almost all of the 1.47 point post-1995 rise in labour productivity growth. On the way down after 2005, the TFP contribution of 2.77 points more than explains the 2.30 point slowdown in labour productivity growth. ICT capital deepening plays virtually no role in explaining these movements for commodities. For market services the story is quite different, as TFP growth (0.69 points) and ICT capital deepening (0.60 points) divide the explanation of the 1.20 point post-1995 speedup in labour productivity growth. Similarly, their respective contributions of 1.00 and 0.92 points neatly divide the recorded post-2005 productivity growth slowdown of 1.96 points. We shall return in subsequent sections to explore this apparent bifurcation of roles for ICT capital deepening as making an important contribution in services while having little to no importance in the commodities sector.

The right half of Table 2 provides the same decomposition for the EU-10. In the top section on the total economy, we see that the initial post-1995 slowdown in labour productivity growth of 0.95 points was explained by TFP growth (0.56 points) and non-ICT capital deepening (0.53 points), with no role for ICT capital deepening. The subsequent post-2005 productivity growth slowdown of 0.63 had as its counterpart a 0.29 point deceleration in TFP growth together with very small contributions of ICT and non-ICT capital deepening (0.17 and 0.07 points, respectively). The balance of contributions was essentially the same in the EU market economy as in the total economy.

Since we are interested in why the EU did not match the post-1995 speedup in productivity growth enjoyed by the United States, we can look from left to right across the market industries section of Table 2 to note that ICT capital deepening in the United States during 1995-2005 of 0.80 points greatly exceeded the 0.37 point ICT contribution for the EU-10. But that is not the whole story, as the contrast in TFP growth between the United States (1.46 points) and the EU-10 (only 0.48 points) was a bigger part of the explanation of U.S. success in this period. We will investigate in a subsequent section whether U.S. industries that were ICT intensive disproportionately enjoyed faster TFP growth during this interval.

As noted above, EU-10 labour productivity growth slowed down between the early (1977-95) period and the late (2005-15) interval much more in the commodities sector than in market services. The early-to-late productivity growth slowdown for commodities of 2.37 points was largely explained by a decline in TFP growth (1.78 points), with virtually no role of ICT capital deepening. Thus the EU experience of commodities was similar to that of the United States in that ICT capital deepening played little to no role on either side of the Atlantic. In the EU market services sector, the early-to-late labour productivity slowdown of 1.08 points is attributed most importantly to non-ICT capital deepening (0.61 points) with smaller roles for

TFP growth (0.27 points) and ICT capital deepening (0.22 points). It thus appears that the industries in the market services sector are those in which the U.S. ICT advantage occurred.

Measures of ICT Intensity and Their Industry Distribution

The relationship between labour productivity growth and ICT intensity is a central issue in this article. Did U.S. industries that were relatively heavy users of ICT experience a relatively large post-1995 productivity growth acceleration and/or a relatively large post-2005 growth slowdown? Did EU-10 ICT-intensive industries have relatively large or small productivity growth slowdowns after 1995 and again after 2005? Can slower productivity growth during 1995-2005 in the EU-10 than in the United States be explained by lower values of ICT indicators in the EU-10?

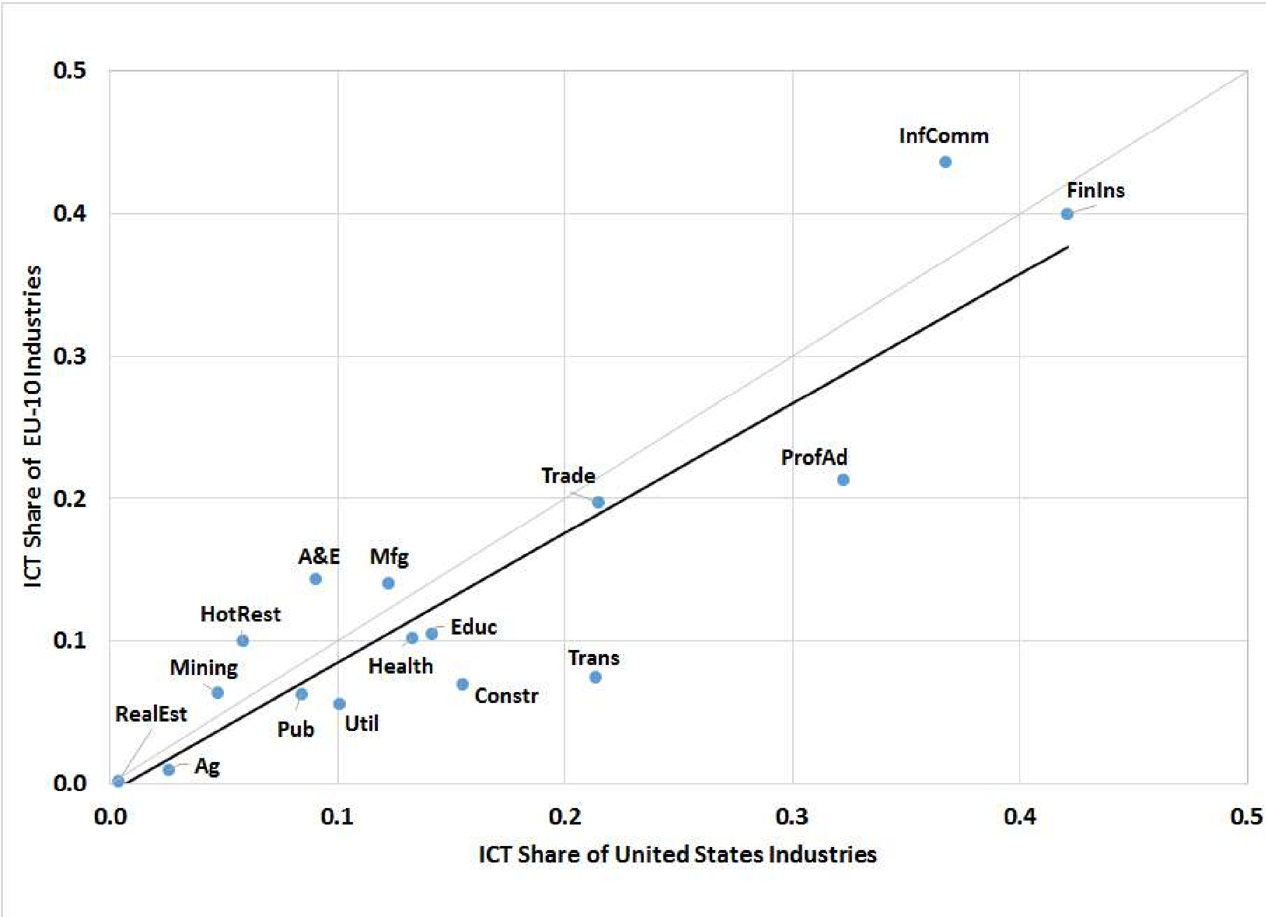
Two alternative ICT-intensity variables are available in the KLEMS data for both the United States and EU-10 and for all 27 of the available industries, including the 16 industrial sectors into which the total economy is divided, as well as the 11 sub-industries within manufacturing. The first of these is the ICT "share indicator," which is formulated as in Stiroh (2002). We compute the average ICT share of investment, which is the annual nominal expenditure on computing equipment, communications equipment and computer software and databases, all divided by the annual nominal expenditure on total capital investment. Initially we examine the actual values of this ratio for individual industries and subsequently in the regressions we convert the share indicator into a share dummy variable equal to unity for industries which are ranked above the median value in the 1991-95 period and zero otherwise.

The other KLEMS ICT variable is the "contribution indicator," equal to the contribution of ICT capital to real value-added growth. This is available at the industry level only beginning in 1999. As with the share indicator, we initially display numerical values of the contribution indicator but for the regression analysis convert it into a dummy variable equal to unity for industries which are ranked above the median value in the 1999-2005 period and zero otherwise. For the regression analysis we also distinguish ICT use from ICT production by creating dummy variables for the "Electric Machinery" industry that produces ICT hardware and the "Information and Communications" industry that produces ICT software and data.

The values of the share indicator for 1991-95 are displayed in Chart 1, where the EU value is plotted on the vertical axis and the U.S. value of the indicator for the same industry is plotted on the horizontal axis. Only the 16 industrial sectors are shown, as there is insufficient space to display clearly the 11 additional manufacturing sub-industries. The thin diagonal 45 degree line indicates equal values for the EU and U.S.; six industries are above that line indicating a higher EU-10 than U.S. value, while 10 are below that line, indicating a lower EU-10 than U.S. value.

The thick diagonal regression line in Chart 1 has a coefficient of 0.91, indicating that the average value of the share indicator for a given industry in the EU-10 is 91 per cent of its value in the United

Chart 1: Correlation between Share of ICT Investment in Total Investment by Industry between the United States and EU-10, 1991-1995



Source: KLEMS Database. Data points can be found in the first column of Table A1 in the online data Appendix available at http://www.csls.ca/ipm/38/gordon-appendix.pdf.

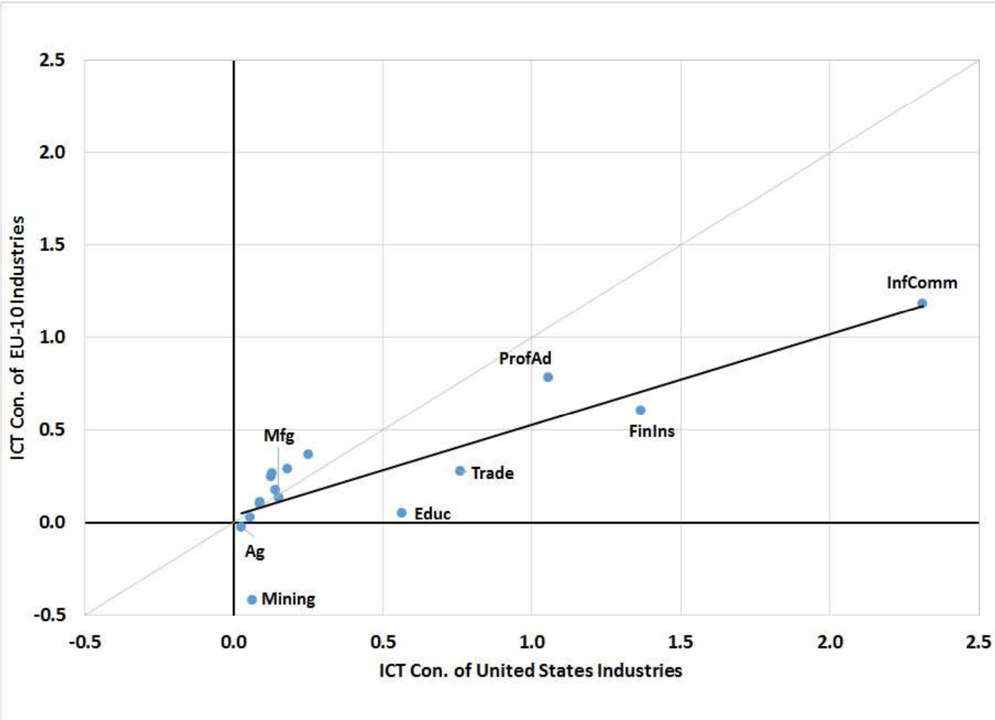
States. Notice that all of the industries with the highest values of the share indicator are in the market services sector – finance/insurance, info/communication, prof/administrative, and trade. The fact that the regression line lies so close to unity suggests that on average a low EU value of the ICT share indicator is not an important explanation of why the EU-10 registered slower productivity growth than the United States during 1995-2005.

Panel A in Chart 2 displays the EU-10 and U.S. values of the alternative contribution ICT indicator for 1999-2005 in the same format as Chart 1. Note that, in contrast to the share indicator, the contribution indicator is less "spread out," with only five of the U.S. industries and only three of the EU-10 industries having a contribution indicator above 0.5. Because of the cluster of dots near the origin in Panel A, we supplement it with Panel B which shows a "zoomed in" version of the same information in the region of 0 to 0.5 on the two axes.

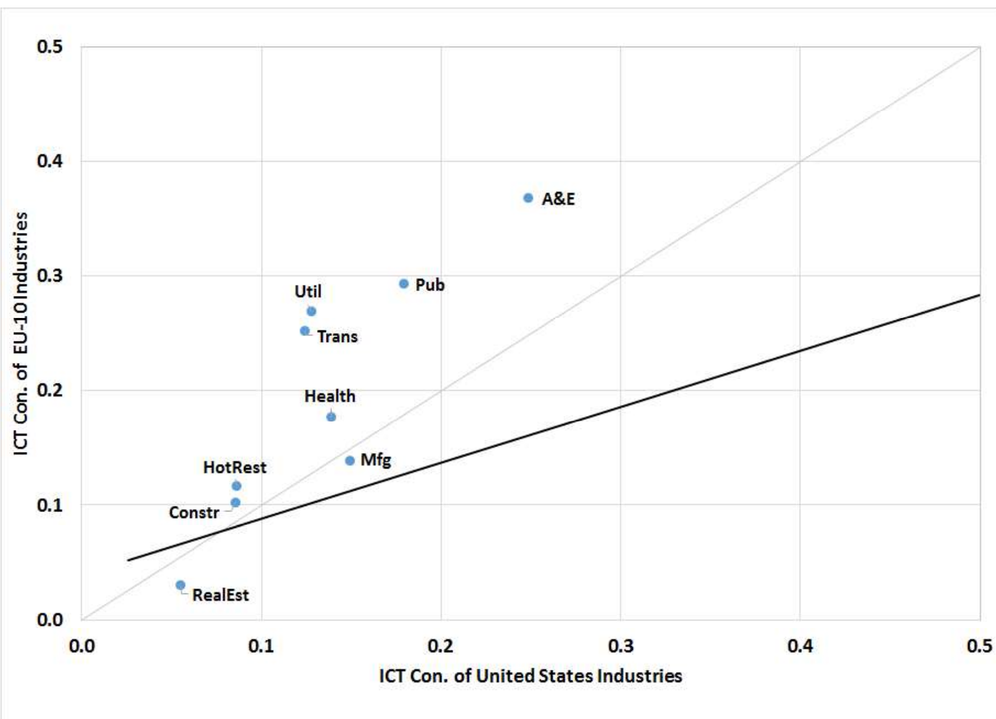
For the contribution indicator the values for the EU-10 are considerably lower on average than in the United States, as summarized by the regression coefficient of 0.49. This indicates that on average the value of

Chart 2: Correlation between Contributions of ICT Capital by Industry between the United States and EU-10, 1999-2005, (Percentage Points per Year)

Panel A: Range 0 to 2.5



Panel B: Range 0 to 0.5



Source: KLEMS Database. Data points can be found in the second column of Table A1 in the online data Appendix available at http://www.csls.ca/ipm/38/gordon-appendix.pdf.

the contribution indicator for a given industry in the EU-10 is roughly half of its value for the counterpart industry in the United States. Since the contribution indicator equals ICT capital's income share times the growth rate of ICT capital, a factor holding back EU-10 labour productivity growth during 1995-2005 was slower growth of ICT capital.[6] Notice that the four service-sector industries that are highest ranked in the United States by the criterion of the contribution indicator are the same as those when ranked by the share indicator.[7]

We have now examined productivity growth rates in Tables 1 and 2 and ICT intensity indicators in the two charts. The effect of ICT intensity on productivity growth is illustrated in Table 3, where we define industries that are intensive in ICT use as those ranked above the median in a ranking of the share indicator. This ranking is carried out separately for the United States and EU-10. By dividing up the industries into these two groups we are able to ask whether industries that are intensive in ICT use had higher growth rates in the United States. 1995-2005 rapid growth period and whether the decline in productivity growth after 2005 in the United States and after 1995 in the EU-10 was concentrated in ICT-use-intensive industries. In addition to separating industries by their intensity of ICT use, we also single out two ICT-producing industries, electric machinery in the commodities sector and information/communications in the market services sector.

Because we obtain roughly the same decomposition using either the share or contribution version of the intensity of ICT use measure, we simplify Table 3 by exhibiting results only for the share version. The top section of the table for the total economy singles out the ICT-producing industries as having much faster productivity growth than the other industry groups in both the United States and EU for all three time periods. This breakdown also highlights the ICT-producing industries as the only group having a post-1995 growth acceleration in the EU, in contrast to the other two groups that experienced a post-1995 growth slowdown. All three industry groups in the EU as well as the United States registered slower productivity growth after 2005.

How do the industries intensive in ICT use compare to the non-ICT industries? For the United States the ICT-use group has faster growth than the non-ICT group by a margin of 2.23 to 1.20 per cent in the middle period but, surprisingly, somewhat slower growth in the first and third time intervals. This means that the ICT-use industries had a much greater 1995-2005 productivity acceleration than the non-ICT in-

6 For example, if the growth rate of ICT capital over a given year is 0.5 and its income share is 0.4, the contribution of ICT capital to productivity growth is 0.2

7 Table A1 in the online Data Appendix lists the actual and dummy values for all U.S. and EU-10 industries of both the share indicator (1991-95) and contribution indicator (1999-2005). Table A1 includes not just the 16 industrial sectors shown in the Charts 1 and 2 but also the 11 sub-industries within manufacturing. Also shown for ease of reference in Table A1 are the growth rates of labour productivity and of TFP in the three sub-intervals between 1977 and 2015 as well as the average 1977-2015 value-added share of each industry and sub-industry to provide a measure of its relative importance.

Table 3: Comparison of Labour Productivity Growth by KLEMS-Based ICT Variables Between United States and EU-10 (Average Annual Rate of Change)

	United States			EU-10		
	1977-1995	1995-2005	2005-2015	1977-1995	1995-2005	2005-2015
Total Economy	1.11	2.17	0.87	2.21	1.26	0.63
ICT-use-intensive	0.78	2.23	0.46	2.52	1.34	0.82
ICT production	4.90	8.04	4.04	3.40	4.08	2.43
non-ICT intensive	0.91	1.20	0.81	1.74	0.82	0.24
Commodities	2.12	3.59	1.29	3.22	2.19	0.85
ICT-use-intensive	0.20	0.58	-0.23	3.27	2.64	1.63
ICT production	10.01	17.57	7.07	5.49	4.78	2.95
non-ICT intensive	1.93	2.88	1.25	2.84	1.52	0.02
Market Services	1.41	2.61	0.65	1.71	1.21	0.63
ICT-use-intensive	1.47	2.86	0.52	1.50	0.77	0.52
ICT production	2.22	4.04	3.05	1.98	3.84	2.26
non-ICT intensive	0.53	0.59	-0.27	2.32	1.34	0.05

Source: KLEMS Database.

dustries (1.45 vs. 0.29 points) as well as a much larger post-2005 slowdown (1.77 vs. 0.39 points). For the EU the ICT-use group registers faster growth than the non-ICT industries in all three periods by a modest margin of 0.78, 0.52, and 0.58 percentage points respectively. This means that the EU early-to-late productivity slowdown was similar in both groups (-1.70 and -1.50 points respectively).

The bottom two sections of Table 3 divide up the market economy into commodities and market services. Again we see for the United States and EU-10 that the ICT-producing industries in the commodities sector (electric machinery) and in the services sector (information/communications) experienced growth accelerations in 1995-2005 and slowdowns in 2005-2015. For the other industries in the United States the commodities and services sectors exhibit very different impacts of ICT use. In the commodities sector the post-1995 acceleration was concentrated in the non-ICT industries with relatively slow productivity growth in the ICT-use group. The opposite was true for market services where the post-1995 acceleration and post-2005 slowdown were much more evident in the ICT-use-intensive industries than in the non-ICT group.

We can gain an understanding of these patterns for the United States by referring back to Chart 1, which displays the value of the ICT share indicator that is used to divide up industries into the ICT-use and non-ICT components for the decomposition of Table 3. Within the commodities sector the construction industry has a relatively high value of the ICT-use indicator but exhibits negative productivity growth of about -1.0 per cent per year in all three time intervals. This is sufficient to hold down overall U.S. productivity growth in the ICT-use segment of the commodities sector. In contrast in the market services sector all the post-1995 acceleration and post-2005 slowdown in productivity growth occurs in the ICT-use industries, four of which are the highest ranked in terms of the ICT-use indicator. These are the industries where we would expect the digital revolution to have its major impact on business efficiency – not only informationcCommunications (which is shown separately on the services "ICT prod" line in Table 3), but also finance/insurance, professional/administrative, and wholesale/retail trade.

For the EU there is much less difference between commodities and services and between intensive ICT use and non-ICT industries. In all these EU-10 industry groups productivity growth slowed down after 1995 and again after 2005. Surprisingly the ICT-producing electric machinery industry in the EU-10 actually experienced slower productivity growth after 1995 despite all the innovation that was driving faster productivity in that industry for the United States. The extent of the EU-10 early-to-late slowdown was greatest in the non-ICT industries (2.82 percentage points in commodities and 2.27 percentage points in services) where productivity growth was zero after 2005. The early-to-late slowdown was somewhat less in the ICT-use-intensive industries (1.64 percentage points in commodities and 0.98 percentage points in services). To this extent intensity of ICT use helped the EU by avoiding the post-2005 productivity paralysis experienced by the EU's non-ICT-intensive industries.

Comparing the EU with the United States for the middle 1995-2005 period, the main sources of EU-10 weakness were in commodities ICT production (i.e., electrical machinery) with 12.79 percentage points slower labour productivity growth related to the United States (4.78 per cent versus 17.87 per cent), non-ICT commodities 1.36 percentage points slower growth (2.88 per cent versus 1.52 per cent), and ICT-use market services 2.09 percentage points slower growth (2.86 per cent versus 0.77 per cent). We return in Table 7 to look more closely at the 1995-2005 performance of particular industries in both the United States and EU-10 that were intensive in ICT use.

Cross-Industry Regression Framework

We have now examined in Table 3 average rates of productivity growth for groups of industries that have a relatively high or low value of our share-based ICT-use-intensity indicator. Now we turn to regressions in which productivity growth in our 27 industry sectors and manufacturing sub-industries constitute the observations to be explained. Our regression framework is adapted from Stiroh (2002), whose specification reflected two time periods, pre- and post-1995 ending in 2000. Here, in contrast, we have three time intervals in which our 1977-2015 overall time period is split at 1995 and 2005. We begin with a simple equation that allows productivity growth to differ across the three intervals:

$$x_{it} = \alpha + \beta_1 M_{it} + \beta_2 L_{it} + \epsilon_{it} \qquad (1)$$

where the "M" ("mid") variable is a dummy equal to unity after 1995, and the "L" ("$late$") variable is a dummy equal to unity after 2005. The constant α represents average labour productivity growth for all industries during 1977-1995. The coefficient β_1 on "M" represents the difference between average labour productivity growth in 1995-2005 minus 1977-1995 for all industries, while the coefficient β_2 on the "L" term is the average difference between

2005-15 minus 1995-2005 for all industries.

We augment this model so that the α term becomes an industry specific constant α_i. This allows us to estimate a fixed effects regression of the form:

$$x_{it} = \alpha_i + \beta_1 M_{it} + \beta_2 L_{it} + \epsilon_{it} \quad (2)$$

Now, the α_i term is the average productivity growth of industry i during 1977-95. This allows greater flexibility in the sense that industries are allowed to start from different initial values of productivity growth prior to 1995. The β_1 term still captures the average productivity growth change of all industries from 1977-95 to 1995-2005, and β_2 measures the average productivity growth change of all industries from 1995-2005 to 2005-2015.

The purpose of our regressions is to capture the effect of ICT-intensity in driving changes in productivity growth that occurred post-1995 and post-2005. The regressions differ from the decomposition of Table 3 in two ways. The first difference is by measuring the *change* in productivity growth across time intervals as contrasted with the *level* of productivity growth as displayed in Table 3. The second difference is that the regressions control for differences across industries in productivity growth during the 1977-95 base period, whereas these differences are not subtracted out in Table 3. Accordingly the regression format can be written as

$$x_{it} = \alpha_i + \beta_1 M_{it} + \beta_2 L_{it} + \gamma_1 M * ICT_{it} + \gamma_2 L * ICT_{it} + \epsilon_{it} \quad (3)$$

The ICT variable is a dummy equal to unity if industry i is ICT intensive, with ICT intensity measured using either the "share" or "contribution" indicator as defined above. With this design, β_1 measures the average post-1995 acceleration of non-ICT-intensive industries, while $\beta_1 + \gamma_1$ captures the average post-1995 change in productivity growth of ICT-intensive industries. γ_1 then captures the *additional* productivity change (up or down) of ICT-intensive industries post-1995 relative to non-ICT industries. Similarly, β_2 represents the post-2005 acceleration or deceleration of non-ICT-intensive industries relative to 1995-2005 while $\beta_2 + \gamma_2$ measures the change in productivity growth of ICT intensive industries, with γ_2 capturing the difference between the two groups.

As in Table 3 we are interested in distinguishing the effect of the two industries that *produce* ICT from the other industries that are relatively intensive in the *use* of ICT. To measure the ICT-production effect, we allow these two industries (electric machinery and information/communication) to have separate coefficients that measure their contribution to the post-1995 and post-2005 changes in productivity growth. This leads us to add in four more regression terms to control for these ICT producing industries, as written in equation (4) below:

$$x_{it} = \alpha_i + \beta_1 M_{it} + \beta_2 L_{it} + \gamma_1 M * ICT_{it} + \gamma_2 L * ICT_{it} + \delta_1 M * EM_{it} + \delta_2 L * EM_{it} + \eta_1 M * IC_{it} + \eta_2 L * IC_{it} + \epsilon_{it} \quad (4)$$

Now the interpretation of the δ_1 term is the additional growth change of the electrical machinery industry relative to ICT-intensive industries; η_1 has a similar interpretation but for the information/communication industry. The δ_2 and η_2 coefficients provide equivalent interpretations for the post-2005 slowdown in productivity growth.

One issue with estimating equations (1) through (4) via ordinary least squares is that each regressor's coefficient will only capture (geometric) average changes in productivity growth. We may be worried about the influence of erratic behavior in relatively "small" industries on our estimates of each of the coefficients. For example, the U.S. agricultural industry experienced a post-1995 acceleration of 3.55 percentage points despite accounting for only 2 per cent of value added in the total economy. To address this issue, we estimate equation (4) using weighted least squares (WLS), with the weight of an industry equal to its value-added (VA) share in 1976. This weighting procedure follows that of Stiroh (2002), which in turn draws on Kahn and Lim (1998), and is based on the reasoning that (1) industries with smaller VA shares should be given less importance in analyzing determinants of aggregate growth and (2) industries with smaller VA shares have noisier productivity growth data. Our choice of the year 1976 preserves exogeneity of the weights, since the first data point in all of our regressions is 1977-78 productivity growth.

Industry Regression Results

Labour Productivity Growth

Table 4 presents results based on equation (4) above, where the observations are annual labour productivity growth rates between 1977 and 2015 for the 27 industries. The left half of the table refers to the United States and the right half refers to the EU-10 aggregate.[8] To conserve space the individual fixed-effect constants for the 27 industries are not listed separately. All columns are estimated with Weighted Least Squares. For the EU-10, data for only 26 industries are utilized, as the "wholesale and retail" industries are consolidated into a single sector in the European KLEMS data.

The grid of "Yes" boxes designates the differences between results listed in the individual columns of the table. Columns (A) and (D) refer to the total economy, while (B) selects the annual observations of the 15 commodities industries (including the sub-industries within manufacturing) and (C) selects the annual observations for the 12 services industries (including both market and non-market services). For the United States, columns (A) through (C) use the share indicator as the ICT-intensity variable while (D) uses the contribution indicator.[9] Thus a comparison of columns (A) and (D) shows the difference made when the contribution indicator in (D) is substituted for the share indicator in (A).

8 There are 27 industries for the United States but only 26 for the EU-10, because data limitations require us to combine the retail and wholesale industries for the EU-10 whereas separate retail and wholesale data are available for the United States.

9 An identical version of this Table with results for only the contribution variable can be found in Appendix Table A2.

We first examine the results for the United States as displayed in columns (A) through (D). The low magnitudes and lack of significance on all U.S. coefficients in line (1) for the post-1995 dummy reflect the fact that non-ICT-intensive industries had little additional productivity growth after 1995 compared to their 1977-95 growth rate. The U.S. ICT-use post-1995 interaction coefficients in line (3) are positive and generally significant (except for commodities industries in column (B)); this suggests that, unlike the non-ICT-intensive industries, the U.S. industries intensive in ICT use had a significant acceleration of productivity growth after 1995. In the total U.S. economy this extra post-1995 growth was 1.64 points for the share indicator and 1.35 points for the contribution indicator, and in the services sector was a considerably higher 2.41 points.

Recall that the post-1995 dummy variable refers to 1995-2015, not 1995-2005, and so the coefficient on the post-2005 dummy variable measures the change in productivity after 2005 as compared to 1995-2005, not as compared to 1977-95. This change in productivity growth after 2005 is shown in lines (2) and (4). There is a modest decline in line (2) for the U.S. non-ICT-intensive industries, but this decline is significant only in the commodities industries. There was a decline for the total U.S. economy in the ICT-use-intensive industries, a significant -1.55 for the share indicator and an insignificant -0.96 for the contribution indicator. The decline was a highly significant -2.66 in the services industries.

When we compare lines (1) and (2) for the U.S. non-ICT-intensive industries, the negative post-2005 coefficients are larger in absolute value than the positive post-1995 coefficients, reflecting the fact that productivity growth was slower after 2005 than before 1995. For the ICT-use-intensive industries the negative post-2005 coefficients are roughly the same size in absolute value as the positive post-1995 coefficients, indicating that for these industries U.S. productivity growth was roughly the same after 2005 as it was before 1995.

The coefficients for the "EM" (electric machinery) industry are shown on lines (5) and (6), where for the United States it appears that there was an enormous and highly significant post-1995 productivity growth acceleration and post-2005 slowdown. This is the industry that produces computer hardware that reached its peak of innovation in the 1995-2005 decade (Oliner-Sichel, 2000). The fact that the negative coefficient for the 2005-15 dummy variable is larger than the positive coefficient for the 1995-2015 dummy variable reflects the fact that productivity growth in this industry was lower after 2005 than before 1995. In contrast the United States coefficients for the "I&C" (information/communications) industry on lines (7) and (8) are all insignificant.

Turning now to the right half of Table 4 for the EU-10 in columns (E) through (H), we can highlight those aspects of the results that differ from those for the United States. The first contrast appears on lines (1) and (2) where (except for the services industries in column (G)) the non-ICT-intensive industries in the EU-10 had a highly significant growth slowdown after 1995 and yet another significant slowdown after 2005. The post-1995 and post-2005 EU-10 slow-

Table 4: Labour Productivity Equations with ICT Dummies, United States versus EU-10, 1977-2015

	United States				EU-10			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
(1) Post-1995	0.35	0.86	0.05	0.35	-0.56**	-1.15**	-0.13	-0.65**
(2) Post-2005	-0.88	-1.90*	-0.29	-1.04	-0.73**	-1.21**	-0.38	-0.74**
(3) Post-1995 X ICT Use	1.64**	-0.06	2.41**	1.35*	0.09	0.73	-0.37	0.28
(4) Post-2005 X ICT Use	-1.55*	0.78	-2.66**	-0.96	0.14	0.23	0.10	0.15
(5) Post-1995 X EM	5.58**	6.76**		5.86 **	-0.25	-0.29		-0.06
(6) Post-2005 X EM	-8.07***	-9.39***		-8.50***	-1.23	-0.85		-1.08
(7) Post-1995 X I&C	-0.17		-0.64	0.11	2.33*		2.36**	2.23*
(8) Post-2005 X I&C	1.44		1.96	1.02	-0.98		-1.30	-0.98
Commodities Only		Yes				Yes		
Services Only			Yes				Yes	Yes
Share Indicator	Yes	Yes	Yes		Yes	Yes	Yes	
Contribution Indicator				Yes				Yes
Number of Observations	1026	570	456	1026	988	570	418	988
Number of Industries	27	15	12	27	26	15	11	26

Source: KLEMS Database.
Note: * indicates statistical significance at the 10 per cent level, ** at the 5 per cent level, and *** at the 1 per cent level. "ICT Use" is a dummy variable equal to unity if the ICT indicator (either share or contribution as defined in the text) is above the median when industries are ranked by the value of that indicator. "EM" is a dummy equal to one for the electrical machinery industry, while "I&C" is a dummy equal to one for the "information & communications" industry. All regressions include industry fixed effects and are estimated by Weighted Least Squares, where WLS weights are taken as an industry's nominal value-added share for 1976. The "Services" category includes the four non-market-economy services-producing industries.

downs were of roughly the same magnitude. Again, in contrast to the United States, there was no additional change up or down in the EU-10 ICT-use-intensive industries as shown in lines (3) and (4). Nor was there any significant growth change in the electric machinery industry in lines (5) and (6), which as we observed in Table 3 above actually experienced slower growth in 1995-2005 than before 1995. The only notable industry effect for the EU-10 was a highly significant post-1995 change in the information/communication industry that was only partly offset by an insignificant post-2005 decrease.

Our overall conclusion from Table 4 is that the United States behaved very differently from the EU-10. The United States experienced little post-1995 or post-2005 change in the rate of productivity growth for the non-ICT-intensive industries but a significant and temporary acceleration especially in the ICT production industries but also in the ICT-use-intensive industries. However, this zig-zag pattern is concentrated in the ICT-use services industries, as well as in the electric machinery industry, but is not evident in the other commodities ICT-use industries. The relative symmetry of these accelerations and decelerations support the broader interpretation that ICT investment in the United States can be viewed as a "temporary shock" that elevated aggregate productivity growth for a decade before dissipating as the fruits of the ICT revolution were reaped. Stated another way, the ICT revolution created a one-time increase in the *level* of U.S. labour productivity that took about a decade to work itself through the economy.

The conclusions for the EU-10 are quite different. There were two successive productivity growth slowdowns, one after 1995 and the second after 2005, and these were concentrated across the 15 industries producing commodities with no additional impact coming from the subset of those services industries that were ICT intensive. Further there were no significant slowdowns in the EU-10 service sector industries whether ICT-intensive or not, with the notable exception of the information/communications industry that experienced a marked increase in productivity growth after 1995 that only partly disappeared after 2005.

Total Factor Productivity Growth

In Table 2 we examined a standard decomposition of sources of growth that divides up contributions to labour productivity growth among labour composition, ICT and non-ICT capital deepening, and a residual TFP growth component. Here we are interested in the channels by which ICT intensity alters productivity growth. We have seen in Table 4 that, for the United States, ICT-intensive industries experienced a temporary acceleration of labour productivity growth during 1995-2005 that was not shared by non-ICT-intensive industries. Is this ICT contribution to growth channeled exclusively through capital deepening? Or, as suggested by Oliner and Sichel (2000), does ICT innovation "spill over" and raise the growth rate of TFP beyond the direct effect of ICT through capital deepening? Oliner and Sichel were particularly interested in the spillover from innovation in the intermediate goods industry making integrated circuit chips to the final goods industry making computer hardware. Here we are interested more generally in spillovers from all types of ICT investment into TFP growth in the industries that are ICT intensive.

Table 5 is arranged just like Table 4, with results for the United States on the left and for the EU-10 on the right. We repeat the results for labour productivity growth in the total economy from Table 4 for ease of comparison with our new results explaining TFP growth. Thus, in Table 5, columns (A) and (B) repeat the U.S. results shown in Table 4 for the total economy, columns (A) and (D). Likewise columns (E) and (F) repeat the EU-10 results shown in Table 5, columns (E) and (H); these differ only in the choice of the ICT indicator.

The new results for TFP growth are shown in columns (C) and (D) for the United States and in columns (G) and (H) for the EU-10. The pattern of significance values and the size of coefficients for each TFP equation are so similar to the corresponding labour productivity equation that the differences are negligible and can be described briefly. For the United States the first six rows of the TFP coefficients in columns (C) and (D) have the same pattern of significance indicators and slightly smaller numerical values as the labour productivity results in columns (A) and (B), except that the post-1995 ICT-intensive acceleration in line (3) column (D) is slightly larger for the TFP equation than the corresponding productivity growth equation in column (B). TFP coefficients are consistently larger in lines (7) and (8) for the I&C industry effect although those coefficients are all insignificantly different from zero and from each other.

The same pattern emerges when the EU-10 TFP growth equations in columns (G) and (H) are compared with the corresponding EU-10 productivity growth equations in columns (E) and (F). Coefficient values and significance levels are almost identical

Table 5: **Labour Productivity and Total Factor Productivity Equations with ICT Dummies, United States versus EU-10, 1977-2015**

	United States				EU-10			
	Labour Productivity		Total Factor Productivity		Labour Productivity		Total Factor Productivity	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
(1) Post-1995	0.35	0.35	0.17	-0.09	-0.56**	-0.65**	-0.70***	-0.69**
(2) Post-2005	-0.88	-1.04	-0.40	-0.46	-0.73**	-0.74**	-0.62**	-0.74**
(3) Post-1995 X ICT Use	1.64**	1.35*	1.34*	1.61**	0.09	0.28	0.46	0.38
(4) Post-2005 X ICT Use	-1.55*	-0.96	-0.96	-0.68	0.14	0.15	0.49	0.69
(5) Post-1995 X EM	5.58**	5.86**	4.41*	4.39*	-0.25	-0.06	0.42	0.87
(6) Post-2005 X EM	-8.07***	-8.50***	-7.34**	-7.56***	-1.23	-1.08	-0.68	-0.07
(7) Post-1995 X I&C	-0.17	0.11	-2.26	-2.28	2.33*	2.23*	3.02**	3.08***
(8) Post-2005 X I&C	1.44	1.02	2.00	1.78	-0.98	-0.98	-1.10	-1.18
Share Indicator	Yes		Yes		Yes		Yes	
Contribution Indicator		Yes		Yes		Yes		Yes
Number of Observations	1026	1026	1026	1026	988	988	988	988
Number of Industries	27	27	27	27	26	26	26	26

Source: KLEMS Database.
Note: * indicates statistical significance at the 10 per cent level, ** at the 5 per cent level, and *** at the 1 per cent level. "ICT Use" is a dummy variable equal to unity if the ICT indicator (either share or contribution as defined in the text) is above the median when industries are ranked by the value of that indicator. "EM" is a dummy equal to one for the electrical machinery industry, while "I&C" is a dummy equal to one for the "information & communications" industry. All regressions include industry fixed effects and are estimated by Weighted Least Squares, where WLS weights are taken as an industry's nominal value-added share for 1976. The "Services" category includes the four non-market-economy services-producing industries.

for the post-1995 and post-2005 non-ICT effects shown on lines (1) and (2). Coefficients for the extra ICT-use-intensive and EM effects are all insignificant in the TFP equations just as they are in the labour productivity equations. However, the "I&C" effect for the information and communications industry shows a post-1995 acceleration that is even larger and more significant in the TFP equations in columns (G) and (H) than in the corresponding labour productivity growth equations in columns (E) and (F).

If the effect of ICT investment was simply to boost labour productivity growth through capital deepening, with no further impact on TFP growth, we would expect no correlation between ICT intensity and TFP growth. If, however, the effect of ICT investment was to cause a reorganization of business practices that went beyond the mere installation of new equipment, we might expect to see that the industry-by-industry differences in labour productivity growth were mirrored in similar differences in TFP growth. Indeed, this appears to be the conclusion implied by the results of Table 5. In the United States those industries that were ICT-intensive experienced a similar acceleration in both labour productivity growth and TFP growth in 1995-2005 that was reversed after 2005. And in the EU-10 all industries (whether ICT-intensive or not) experienced a similar deceleration in both labour productivity growth and TFP growth after 1995 and again after 2005.

Cross Effects

Are the differences in productivity and TFP growth between the United States and EU-10 industries due to differing values of ICT indicators or to a differing responsiveness to those indicators? That question can be answered by looking at "cross effects," the results of recalculating predicted values from the regression equations with values of the ICT indicators and regression coefficients from opposite sides of the Atlantic.

The top section of Table 6 reports the results for the United States and the bottom section shows those for the EU-10. Calculations for labour productivity growth are shown on the left and for TFP growth are shown on the right. Since we are interested in the effect of the actual values of the ICT indicators, not just whether they are set equal to 0 or 1 as in the regressions of Tables 4 and 5, we base the results of Table 6 on alternative versions of the productivity and TFP equations in which the 0 or 1 values of the ICT indicator dummy variable are replaced by the numerical values of the ICT indicator.

We could base these calculations on the ICT share indicator or the ICT contribution indicator. However, as shown above in Chart 1, the EU-10 values of the ICT share indicator are quite similar to the U.S. values, with a regression coefficient of 0.91 of EU-10 indicator values for each industry on U.S. indicator values. Thus it is not surprising that it makes little difference when we recalculate predicted values of productivity growth by substituting the share indicator values from across the Atlantic. All the difference in predicted values comes from differing coefficients in the productivity equations and none from differing share indicator values.

The results using the ICT contribution indicators are more interesting, since as shown in Chart 2 above the EU-10 contribution indicator values are quite different than the United States values, having a coefficient of 0.49 when regressed on United States indicator values. The estimated coefficients of the alternative "continuous value" versions of the ICT contribution equations are shown in Appendix Table A3.

The top row and left column of Table 6 shows for the total U.S. economy that the actual productivity growth rate for 1995-2005 was 2.17 per cent. Underneath this actual value, line (A1) shows that the predicted value of labour productivity growth when using the continuous version of the ICT contribution equation is a nearly identical 2.20 per cent. If EU-10 data for the ICT contribution indicator are substituted for the U.S. values, the predicted value declines by -0.24 percentage points to 1.96, as shown in line A2. Then line A3 shows that if we switch back to U.S. data for the contribution indicator and use the EU-10 regression coefficients, the predicted value falls to 1.78, -0.42 below the predicted value of 2.20 when the same U.S. indicator values are combined with U.S. regression coefficients. Finally with EU-10 values for both the indicator data and the regression coefficients, the predicted value falls to 1.69 per cent, or -0.27 points below the 1.96 predicted value when EU data are combined with U.S. coefficients. Thus, U.S. productivity growth was faster than in the EU-10 for 1995-2005 *both* because the U.S. values of the ICT contribution indicator were higher and also because U.S. ICT-intensive industries had a substantially greater positive post-1995 productivity growth response relative to U.S. non-ICT-intensive industries than occurred in the EU-10.

The bottom half of Table 6 in the first column shows that this same interpretation works in reverse for the EU-10. With

Table 6: Cross Effects for EU-10 and U.S. Labour Productivity and TFP (Average Annual Rate of Change)

	Labour Productivity		Total Factor Productivity	
	1995-2005	2005-15	1995-2005	2005-15
Actual U.S. Data	2.17	0.87	0.70	0.17
(A) Predicted U.S. Values with				
(1) U.S. ICT coefficients and U.S. ICT data	2.20	0.60	0.73	-0.11
(2) U.S. ICT coefficients and EU ICT data	1.96	0.64	0.47	-0.22
(3) EU ICT coefficients and U.S. ICT data	1.78	1.14	0.28	0.57
(4) EU ICT coefficients and EU ICT data	1.69	0.98	0.18	0.21
Actual EU-10 Data	1.26	0.63	0.27	-0.02
(B) Predicted EU-10 Values with				
(1) EU ICT coefficients and EU ICT data	1.69	1.02	0.33	-0.09
(2) EU ICT coefficients and U.S. ICT data	1.78	1.19	0.43	0.27
(3) U.S. ICT coefficients and EU ICT data	1.96	0.68	0.61	-0.52
(4) U.S. ICT coefficients and U.S. ICT data	2.21	0.65	0.88	-0.41

Source: KLEMS Database.
Note: Coefficient estimates are taken from the specifications in Table 5, where the 0,1 ICT intensity dummy variables for the contribution indicator are replaced by the continuous numerical values of that indicator as listed in Table A1 of the online Data Appendix. These coefficient estimates can be found in columns (B), (D), (F), and (H) of Table A3. The online Data Appendix is available at http://www.csls.ca/ipm/38/gordon-appendix.pdf.

its own indicator data and regression coefficients, the predicted EU-10 productivity growth in 1995-2005 is 1.69 per cent. Substituting U.S. indicator data raises predicted productivity growth from 1.69 to 1.78 per cent using EU regression coefficients and from 1.96 to 2.21 per cent using U.S. regression coefficients. Substituting U.S. regression coefficients raises the predicted value from 1.69 to 1.96 per cent using EU indicator data and from 1.78 to 2.21 per cent using U.S. indicator data. Thus 1995-2005 EU-10 productivity growth was slower than in the United States both because EU-10 ICT contribution data were smaller and also because EU-10 ICT-intensive industries had virtually no excess 1995-2005 productivity growth response relative to EU non-ICT intensive industries as compared to a substantial excess response in the United States.

Turning to the second column in Table 6, the top section for the United States shows the predicted values of labour productivity growth for 2005-15, when actual growth rate of 0.87 was much slower than the 2.17 per cent actual rate recorded for 1995-2005. A comparison of lines A1 and A2 indicates that the negative U.S. post-2005 ICT coefficients generate a predicted value of 0.60 per cent with the U.S. indicator data and a similar 0.64 per cent with the EU indicator data. A switch from the negative U.S. post-2005 coefficients on line A1 to the positive EU post-2005 coefficients on line A3 causes a jump in the predicted value from 0.60 to 1.14 per cent. With EU indicator data, the same switch from U.S. to EU coefficients causes a smaller jump in the predicted value from 0.64 to 0.98 per cent when the EU indicator values are used, because the size of those EU indicators is smaller (recall Chart 2).

For the EU in the bottom half of column (2) substituting the U.S. indicator values makes a relatively small difference. A much larger difference occurs when the negative U.S. coefficients are substituted for the positive EU coefficients. This switch of coefficients with EU indicator values changes predicted productivity growth from 1.02

per cent on line B1 to 0.68 per cent on line B3. The same switch in coefficients with U.S. indicator values changes predicted productivity growth from 1.19 per cent on line B2 to 0.65 per cent on line B4 – the drop in predicted growth in this case is greater because U.S. indicator values are larger and are applied to negative coefficients.

The right half of Table 6 repeats the same exercise for the same equations when TFP growth is used as the dependent variable instead of labour productivity growth. Again we reach the conclusion that both indicator values and estimated coefficients matter in the interpretation of differences in behavior between the United States and the EU. after 1995 and again after 2005. In the 1995-2005 interval the United States enjoyed a TFP growth acceleration not only because U.S. ICT-intensive industries had higher values of the ICT contribution indicator, but also because TFP growth responded by a greater positive amount than in the EU-10 to that ICT indicator. The EU-10 not only had lower values of the ICT contribution indicator in several industries, as shown in Chart 2, but also had a much smaller (and insignificant) positive productivity response to the ICT contribution indicator.

After 2005, TFP growth slowed down on both sides of the Atlantic. In the United States this slowdown was concentrated in ICT-intensive industries as suggested by the negative ICT post-2005 coefficients. Predicted TFP growth is higher when the small but positive EU ICT coefficients are substituted for the large negative U.S. ICT coefficients. In contrast the EU-10 experienced a balanced TFP growth slowdown after 2005, with only small (and insignificant) positive coefficients in the ICT-intensive industries. So when the relatively large and negative U.S. coefficients are substituted for the relatively small and positive EU post-2005 ICT coefficients, predicted growth is substantially lower.

Which Industries Drive the Results?

A central result that emerges from our regression analysis is that the 1995-2005 acceleration in U.S. labour productivity and TFP growth together with the subsequent post-2005 U.S. growth slowdown were both driven not just by ICT production in the electric machinery industry but by ICT-use-intensive industries in the services sector. It appears that this post-1995 ICT stimulus does not occur in ICT-intensive commodities-producing industries once the special role of the electric machinery industry is taken into account. Which are the specific ICT-intensive industries in the services sector that account for post-1995 U.S. productivity growth behavior?

Table 7 is designed to answer this question. The top section shows the top six industries in the market sector when ranked by the value of the contribution indicator of ICT intensiveness. Displayed for each industry are the U.S. and EU values of the contribution indicator, the 1995-2005 growth rate of labour productivity in the United States and EU as well as the difference between them, and the share of each industry in market-sector value added. The top four industries (highlighted on the right side of Chart 2) are all in the services sector and the next two are in manufacturing. Not surprisingly the list includes informa-

Table 7: Comparative Data for Focus Industries, United States versus EU-10

	ICT Contribution Indicator		Labour Productivity Growth			Market Value-Added Share
Industry	U.S. 1999-2005	EU-10 1999-2005	U.S. 1995-2005	EU-10 1995-2005	U.S.- EU-10 1995-2005	U.S. 1977-2015
Group 1: High U.S. ICT Indicator						
Information & Communications	2.31	1.18	4.04	3.84	0.20	0.09
Finance & Insurance	1.36	0.61	3.77	2.14	1.63	0.09
Professions & Administrative	1.05	0.79	1.20	-1.03	2.23	0.12
Wholesale & Retail	0.70	0.28	4.33	1.81	2.53	0.19
Electrical Machinery	0.53	0.12	17.57	4.78	12.80	0.03
Other Manufacturing	0.27	0.12	3.32	2.82	0.50	0.01
Group 2: Low U.S. ICT Indicator but Rapid U.S. 1995-2005 LP Growth						
Petroleum	0.13	0.22	10.99	-0.39	11.38	0.01
Agriculture	0.03	-0.02	7.27	3.47	3.80	0.02
Transportation Equipment	-0.03	0.24	4.63	2.58	2.05	0.03
Textiles & Apparel	0.04	0.02	3.63	2.99	0.64	0.01
Chemicals	0.07	0.16	3.22	4.05	-0.83	0.03
Rubber & Plastics	0.14	0.10	3.19	2.42	0.77	0.01
Machinery NEC	-0.09	0.16	3.02	2.86	0.16	0.02

Source: KLEMS Database and Table A1.

tion/communications, which produces data and software, as well as electric machinery, which produces ICT hardware. Also included are the finance/insurance and professional/administrative industries that are heavy users of ICT equipment and software, and the wholesale/retail sector. As shown in the far right column, these six industries account for 53 per cent of U.S. market-sector value added.

Notably, all of the six industries have faster 1995-2005 labour productivity growth in the United States than in the EU. While the margin is slimmer in information/communications and other manufacturing, the difference is large in the four remaining industries and massive in Electric Machinery. Part of this difference in labour productivity growth between the United States and EU is explained by the first two columns that show a substantially higher value of the ICT indicator in the United States than in the EU. But, as shown by the cross-effects analysis of Table 6, higher U.S. productivity growth is explained not just by higher values of the ICT indicator but also by a greater response of productivity growth to a given value of that indicator.

But these six ICT-intensive industries were not the only reason that U.S. productivity growth was temporarily high during 1995-2005. Shown in the bottom section of Table 7 are seven additional industries ranked by their 1995-2005 U.S. labour productivity growth. All of the seven are commodities-producing, and six are subindustries within manufacturing. What distinguishes these U.S. industries is that they all achieved rapid productivity growth faster than 3.0 per cent in 1995-2005 with relatively small values (all below 0.15) of the ICT contribution indicator. In all of these industries but chemicals manufacturing, the U.S. rate of productivity growth was faster than in the EU, very substantially so in the case of petroleum and agriculture.

This list of seven commodities-producing industries that experienced rapid U.S. productivity growth during 1995-2005 provides a cautionary note to generalizations that credit ICT in general, or ICT only in the services sector, for all of the post-1995 U.S. productivity growth acceleration. These seven industries all had relatively low values of the contribution-based ICT indicator and so achieved their growth for reasons other than a large infusion of ICT investment.[10] Notably, with the exception of petroleum, 1995-2005 productivity growth in the EU-10 in this group of industries was relatively healthy with a relatively modest shortfall compared to U.S. productivity growth.

Summary and Conclusions

A retardation in the growth of labour productivity and of total factor productivity (TFP) has characterized both the United States and western Europe since the 1970s, in the sense that growth has been slower since 2005 than it was before 1995. The notable difference in performance across the Atlantic occurred in the middle interval of 1995-2005, when a sharp acceleration of growth in the United States contrasted to a growth slowdown in western Europe. As a result, the story of U.S. productivity growth since the mid-1970s has been one of slow-fast-slow over the three intervals divided at 1995 and 2005, in contrast to a two-step deceleration in Europe.

A substantial literature about the 1995-2005 U.S. productivity growth revival credits most or all of it to a surge of innovation and investment in information and communication technology (ICT). Does this finding of a dominant role for ICT hold up to a new examination of the data? If so, how is the post-2005 U.S. growth slowdown explained? If valid, the dominant role for ICT during 1995-2005 raises questions about the European slowdown that occurred at the same time. Did Europe invest less in ICT or was its problem a weaker implementation of new ICT hardware and software? In which industries did Europe lag most substantially behind the U.S. growth performance, and were these industries relatively heavy users or producers of ICT investment?

This article explores these questions at the level of the total economy and of 27 separate industries in the EUKLEMS dataset that allows us to study sources of productivity growth and to develop alternative indicators of "ICT-intensity" for individual industries on both sides of the Atlantic. To avoid being swamped by industry-level data for numerous European countries, we have combined time series for 10 western European countries into an aggregate that we call the "EU-10" that can be compared directly to data for the United States.

Our initial assessment is based on a decomposition of sources of growth in which labour productivity growth is divided up among the contributions of ICT and non-

10 These industries also had relatively low values of the alternative share ICT indicator, as shown in Appendix Table A1.

ICT capital deepening, changes in labour quality, and changes in TFP. Surprisingly, in view of the emphasis in past literature on the role of ICT, we find that the direct contribution of ICT capital deepening accounts for one-third or less of the post-1995 U.S. productivity growth revival or post-2005 growth slowdown. For the EU-10 ICT capital deepening plays virtually no role in explaining the two-step productivity growth slowdown. About one-third of the faster labour productivity growth during 1995-2005 in the United States vs. the EU-10 is explained by the higher contribution of ICT capital deepening in the United States. Thus, the growth accounting exercise appears to contradict the emphasis in much past literature on the dominant role of ICT in the post-1995 U.S. growth revival.

To measure ICT intensity we develop two indicators, one based on the ICT share of total investment and the other based on the KLEMS measure of the ICT contribution to value-added growth. When industries are divided up into "ICT producing," "ICT-use-intensive" and "non-ICT-intensive", we emerge with a different conclusion regarding the importance of ICT for U.S. behavior. Most of the post-1995 U.S. productivity growth revival and post-2005 slowdown occur in industries classified as either ICT-producing or ICT-use-intensive. This is particularly true in the services sector where the industries with the highest values of our ICT indicators are located. For the EU-10, the story is simpler, as the two-step slowdown occurs equally in all three categories of industries except for the ICT-producing information/communications ("I&C") industry.

We run regressions for 27 industries on annual data for 1977-2015 to measure the response of labour productivity and alternatively TFP growth across the three periods to ICT intensity. Separate responses are included for the ICT-producing electric machinery ("EM") and I&C industries. The results support the role of ICT-intensive industries in the services sector as the main locus of the post-1995 U.S. growth revival and post-2005 growth slowdown, with a major extra contribution coming from the ICT-producing EM industry. The EU-10 regressions indicate no additional role of ICT-intensive industries in causing the two-step productivity deceleration beyond the contribution of the non-ICT-intensive industries plus the ICT-producing I&C industry.

Why does the initial growth accounting exercise suggest a minimal U.S. role for ICT but the ICT decomposition and ICT regressions support a major U.S. role? The answer is provided when the dependent variable in the regressions is switched from growth in labour productivity to growth in TFP. The coefficients are almost identical, indicating that the ICT stimulus to productivity growth operates through spillovers to TFP growth, not just via the ICT capital-deepening effect as measured in the growth-accounting exercise. There is no separate ICT influence on TFP growth in the EU-10 with the exception of the I&C industry.

While the post-2005 slowdown in U.S. productivity growth is largely symmetric with the post-1995 growth acceleration, there is a noticeable difference. Non-ICT-intensive industries in the commodities sector contribute more to the post-2005 slowdown than to the post-1995 revival. While this is true of all non-ICT U.S. commodities industries, the post-2005 slowdown in the ICT-producing EM industry is particularly sharp, reinforcing the temporary character of the late 1990s ICT revolution.

A few differences stand out in the results for the EU-10. In most respects the two-step slowdown after 1995 and again after 2005 were unrelenting, applying to all industries. There is a modest tendency for ICT-intensive commodities industries in the EU-10 to have most of their slowdown after 2005 rather than after 1995, indicating that ICT investment may have "buoyed" productivity growth enough largely to offset the other causes of the 1995-2005 EU slowdown. After 2005, productivity growth dropped across all EU-10 industries. The role of ICT-producing industries is quite different in the EU-10, with a much weaker performance in hardware-producing EM but a strong performance almost up to the U.S. achievement in software-producing I&C.

Overall the results support a strong role for ICT-intensive industries, particularly in the market services sector, in driving the U.S. 1995-2005 productivity growth acceleration. We find that the standard growth accounting approach is deficient when it separates sources of growth between growth in ICT capital deepening and TFP growth, because much of the effect of the U.S. ICT revolution appears to have been channeled through spillovers to TFP growth rather than being limited to the capital deepening pathway. Three aspects of the U.S. 1995-2005 ICT revolution stand out besides its spilling over to TFP growth. First, the growth-inducing aspects of the revolution were temporary, as growth rates in almost every industry went into reverse after 2005. Second, the sharpest decline in productivity growth occurred at the heart of the ICT revolution in the production of electric machinery, the industry that produces ICT hardware, with less of a relative slowdown in the software-producing I&C industry. Third, there were sharp post-2005 declines in several commodities-producing industries that were minimal users of ICT, including especially agriculture, petroleum, and across the board in manufacturing sub-industries.

Why did the EU-10 fail to benefit from the ICT revolution and instead did it experience a two-step slowdown in labour productivity and TFP growth? The diagnosis has numerous components. Despite all the U.S.-led innovation that drove its ICT-hardware EM industry to register a 17 per cent annual rate of productivity growth in 1995-2005, that industry in the EU-10 actually experienced a productivity growth slowdown during 1995-2005. The EU-10 had substantially lower values of the contribution-based ICT-use-intensity indicator variable. The regressions indicate virtually no difference in the extent of the EU growth slowdown experienced by ICT-intensive versus non-intensive industries, indicating a failure of EU industries to exploit the efficiency opportunities provided by the limited ICT investment that did occur. And finally the EU-10 shortfall in productivity growth during 1995-2005 can be traced to particular industries in which performance fell far short of that in the U.S. These outlier industries include not just ICT-producing electric machinery but also agriculture, petroleum refining, and the large wholesale and retail sector where for many reasons EU nations lagged behind the U.S in adopting the big-box retail format which exploited the opportunities provided by the ICT revolution.

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Data Appendix to "Transatlantic Technologies: The Role of ICT In the Ascent and Descent of U.S. and European Productivity Growth"

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Table 1: Summary of ICT Variables and Indicators for the U.S. and EU-10

	ICT Values		Productivity Growth			Total Factor Productivity Growth			Value-Added Share
United States									
Industry	Share	Contribution	1977-1995	1995-2005	2005-2015	1977-1995	1995-2005	2005-2015	1977-2015
Agriculture	0.03	0.03	2.57	7.27	1.05	2.77	5.62	-0.42	0.01
Mining	0.05	0.06	2.66	-1.87	2.98	-0.02	-2.04	4.54	0.02
Manufacturing	0.12	0.15	2.85	5.53	1.90	1.52	3.18	0.28	0.16
Utilities	0.10	0.13	1.22	1.20	-0.03	-0.15	-1.18	-1.14	0.02
Construction	0.15*	0.09	-0.97	-1.02	-0.92	-1.09	-1.79	-1.69	0.04
Wholesale & Retail			-	-	-	-	-	-	-
Wholesale	0.28*	1.02*	3.32	6.13	0.81	1.65	4.57	-0.08	0.06
Retail	0.16*	0.52*	2.37	5.38	0.66	1.46	3.05	0.30	0.07
Transportation	0.21*	0.12	2.45	1.48	-0.69	1.95	0.51	-1.10	0.04
Hotels & Restaurants	0.06	0.09	0.13	1.81	-0.67	-0.06	1.21	-0.71	0.03
Information & Communications	0.37*	2.31*	2.22	4.04	3.05	1.77	1.02	1.66	0.06
Finance & Insurance	0.42*	1.36*	0.94	3.77	0.80	-3.05	1.03	-0.22	0.06
Real Estate	0.00	0.05	0.96	0.96	1.91	-0.20	-0.04	1.34	0.11
Professions & Administrative	0.32*	1.05*	-0.76	1.20	1.07	-1.72	-1.30	0.43	0.08
Public Sector	0.08	0.18*	0.21	0.55	0.33	-1.08	-0.30	-0.39	0.14
Education	0.14*	0.56*	-0.46	0.87	0.99	-1.30	-0.16	0.29	0.01
Health	0.13*	0.14*	-1.38	-0.25	0.34	-1.92	-0.89	-0.22	0.06
Arts & Entertainment	0.09	0.25*	0.94	-0.05	-0.10	0.89	-0.70	-0.36	0.03
Manufacturing Sub-Industries									
Food	0.10	0.13	3.14	0.05	-0.43	1.74	-1.18	-1.10	0.02
Textiles & Apparel	0.08	0.04	3.64	3.63	1.20	2.44	1.28	-0.41	0.01
Wood & Paper	0.09	0.13*	0.26	2.15	1.46	-0.85	1.13	0.38	0.01
Petroleum	0.10	0.13	4.81	10.99	-1.08	2.94	9.84	-5.00	0.01
Chemicals	0.10	0.07	2.12	3.22	1.37	0.22	-0.77	-2.07	0.02
Rubber & Plastics	0.07	0.14*	2.63	3.19	-0.78	1.84	1.69	-1.55	0.01
Metals	0.14*	0.00	2.07	2.25	0.50	1.18	1.47	-0.21	0.02
Electrical Machinery	0.16*	0.53*	10.01	17.57	7.07	8.32	14.23	5.53	0.02
Machinery NEC	0.21 *	-0.09	0.14	3.02	0.64	-1.36	0.55	-0.19	0.01
Transportation Equipment	0.10	-0.03	0.50	4.63	2.26	-0.21	2.43	1.48	0.02
Other Manufacturing	0.12*	0.27*	1.06	3.32	1.79	0.14	1.32	0.63	0.01
EU-10									
Agriculture	0.01	-0.02	4.46	3.47	1.37	4.46	2.78	0.59	0.02
Mining	0.06	-0.42	4.71	-0.72	-0.29	0.71	-0.47	-1.72	0.01
Manufacturing	0.14	0.14	3.38	2.87	1.84	1.72	1.46	0.89	0.20
Utilities	0.06	0.27*	2.64	3.21	-1.38	0.47	0.69	-2.17	0.03
Construction	0.07	0.10	1.34	-0.10	-0.30	0.87	-0.32	-1.06	0.06
Wholesale & Retail	0.20*	0.28*	2.29	1.81	1.29	1.09	0.74	0.58	0.11
Transportation	0.07	0.25*	3.61	2.46	0.42	2.38	0.94	-0.41	0.05
Hotels & Restaurants	0.10	0.12	-0.60	-0.52	-0.58	-1.21	-1.06	-0.51	0.03
Information & Communications	0.44*	1.18*	1.98	3.84	2.26	0.09	2.87	1.63	0.04
Finance & Insurance	0.40*	0.61*	1.35	2.14	1.14	0.01	0.49	0.31	0.05
Real Estate	0.00	0.03	-1.24	-0.21	0.58	0.57	0.14	0.04	0.09
Professions & Administrative	0.21*	0.79*	0.59	-1.03	-0.24	-1.23	-1.96	-0.71	0.09
Public Sector	0.06	0.29*	1.43	1.26	1.11	0.51	0.00	0.33	0.07
Education	0.11	0.05	0.59	-0.19	-0.70	-0.10	-1.07	-0.97	0.05
Health	0.10	0.18*	0.13	0.36	0.22	-0.45	-0.32	-0.10	0.06
Arts & Entertainment	0.14*	0.37*	0.58	0.40	-0.51	-0.67	-0.70	-0.86	0.03
Manufacturing Sub-Industries									
Food	0.12*	0.13	2.17	0.92	0.42	0.72	-0.01	-0.13	0.03
Textiles & Apparel	0.17*	0.02	3.30	2.99	2.11	1.76	1.61	1.27	0.01
Wood & Paper	0.15*	0.20*	2.48	2.38	2.02	1.14	1.27	1.51	0.01
Petroleum	0.07	0.22*	-0.84	-0.39	-3.53	-3.72	-1.62	-6.01	0.00
Chemicals	0.11*	0.16*	5.40	4.05	1.94	3.64	1.92	0.88	0.02
Rubber & Plastics	0.10	0.10	3.32	2.42	1.42	1.89	1.92	0.41	0.02
Metals	0.09	0.10	2.85	2.01	1.62	2.19	1.19	0.90	0.03
Electrical Machinery	0.23*	0.12	5.49	4.78	2.95	2.73	2.91	2.09	0.02
Machinery NEC	0.17*	0.16	2.58	2.86	0.97	1.26	1.70	0.04	0.02
Transportation Equipment	0.12*	0.24*	3.81	2.58	3.15	1.70	1.11	1.71	0.02
Other Manufacturing	0.18*	0.12	1.09	2.82	1.12	0.33	2.17	0.57	0.02

Source: KLEMS Database. A "*" next to a nominal variable indicates that the dummy variable for that industry is equal to one; the dummy is zero otherwise. The "Share" variable is the nominal share of ICT investment in total investment of an industry from 1991-1995. The "Contribution" variable is the 1999-2005 contribution of ICT-capital to real value-added. Dummies are marked as one for these nominal variables if an industry's nominal ICT variable is above the median, and zero otherwise.

Table 2: Labour Productivity Equations with ICT Dummies for Contribution Indicator, U.S. vs. EU-10, 1977-2015

	United States			EU-10		
	(A)	(B)	(C)	(D)	(E)	(F)
(1) Post-1995	0.35	0.74	-0.19	-0.65**	-0.95**	-0.20
(2) Post-2005	-1.04	-1.55*	-0.33	-0.74**	-0.88*	-0.53
(3) Post-1995 X ICT Use	1.35*	0.78	1.91*	0.28	0.42	-0.12
(4) Post-2005 X ICT Use	-0.96	-0.44	-1.67	0.15	-0.93	0.30
(5) Post-1995 X EM	5.86**	6.05*		-0.06	0.23	
(6) Post-2005 X EM	-8.50***	-8.50**		-1.08	-0.94	
(7) Post-1995 X I&C	0.11		0.10	2.23*		2.18**
(8) Post-2005 X I&C	1.02		1.02	-0.98		-1.35
Commodities Only		Yes			Yes	
Services Only			Yes			Yes
Number of Observations	1026	570	456	988	570	418
Number of Industries	27	15	12	26	15	11

Source: KLEMS Database.
Note: * indicates statistical significance at the 10 per cent level, ** at the 5 per cent level, and *** at the 1 per cent level. "ICT Use" is a dummy variable equal to unity if the ICT indicator (either share or contribution as defined in the text) is above the median when industries are ranked by the value of that indicator. "EM" is a dummy equal to one for the Electrical Machinery industry, while "I&C" is a dummy equal to one for the "Information & Communications" industry. All regressions include industry fixed effects and are estimated by Weighted Least Squares, where WLS weights are taken as an industry's nominal value-added share for 1976. The "Services" category includes the four non-market-economy services-producing industries.

Table 3: Labour Productivity and Total Factor Productivity Equations with Continuous Measure of ICT, U.S. vs. EU-10, 1977-2015

	United States				EU-10			
	Labour Productivity		Total Factor Productivity		Labour Productivity		Total Factor Productivity	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
(1) Post-1995	0.11	0.43	-0.18	0.07	-0.75**	-0.67**	-0.99***	-0.68**
(2) Post-2005	-0.36	-0.85	-0.11	-0.41	-0.74*	-0.81**	-0.83**	-0.86***
(3) Post-1995 X ICT Use	6.55*	1.92*	6.51*	2.11**	1.88	0.69	3.86*	0.80
(4) Post-2005 X ICT Use	-8.33*	-2.17*	-4.97	-1.26	0.54	0.62	3.29	2.04*
(5) Post-1995 X EM	39.10**	11.60**	30.90**	8.99*	-1.72	-1.07	1.23	6.48
(6) Post-2005 X EM	-53.90***	-16.20***	-47.70***	-14.50***	-5.27	-9.21	-3.23	-1.65
(7) Post-1995 X I&C	-1.91	-1.32	-8.05	-2.46 **	4.10	1.45	4.76	2.13*
(8) Post-2005 X I&C	6.62	2.10	6.99	1.71	-2.46	-1.27	-4.23	-2.35*
Share Indicator	Yes		Yes		Yes		Yes	
Contribution Indicator		Yes		Yes		Yes		Yes
Number of Observations	1026	1026	1026	1026	988	988	988	988
Number of Industries	27	27	27	27	26	26	26	26

Source: KLEMS Database.
Note: * indicates statistical significance at the 10 per cent level, ** at the 5 per cent level, and *** at the 1 per cent level. "ICT Use" is a dummy variable equal to unity if the ICT indicator (either share or contribution as defined in the text) is above the median when industries are ranked by the value of that indicator. "EM" is a dummy equal to one for the Electrical Machinery industry multiplied by its ICT value, while "I&C" is a dummy equal to one for the "Information & Communications" industry multiplied by its ICT value. All regressions include industry fixed effects and are estimated by Weighted Least Squares, where WLS weights are taken as an industry's nominal value-added share for 1976. The "Services" category includes the four non-market-economy services-producing industries.

Table 4: Chart 1 Data

Industry	US Share	EU-10 Share	45degree	
Ag	0.03	0.01	0	0
Mining	0.05	0.06	1	1
Mfg	0.12	0.14		
Util	0.10	0.06		
Constr	0.15	0.07		
Trade	0.21	0.20		
Trans	0.21	0.07		
HotRest	0.06	0.10		
InfComm	0.37	0.44		
FinIns	0.42	0.40		
RealEst	0.00	0.00		
ProfAd	0.32	0.21		
Pub	0.08	0.06		
Educ	0.14	0.11		
Health	0.13	0.10		
A&E	0.09	0.14		

Table 5: Chart 2 Data

Industry	US Share	EU-10 Share	45degree	
Ag	0.03	-0.02	0	0
Mining	0.06	-0.42	1	1
Mfg	0.15	0.14		
Util	0.13	0.27		
Constr	0.09	0.10		
Trade	0.76	0.28		
Trans	0.12	0.25		
HotRest	0.09	0.12		
InfComm	2.31	1.18		
FinIns	1.36	0.61		
RealEst	0.05	0.03		
ProfAd	1.05	0.79		
Pub	0.18	0.29		
Educ	0.56	0.05		
Health	0.14	0.18		
A&E	0.25	0.37		

Lessons from Productivity Comparisons of Germany, Japan, and the United States

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Abstract

Germany, Japan and the United States are the three largest mature economies and set the productivity frontier in most industries. In aggregate, Germany caught up to US productivity by the 1990s but Japan remains well below the leaders and has the potential for faster growth. The article estimates the industry productivity leaders in the 1990s and whether lagging industries subsequently caught up to the leader. Germany lags the United States in some industries, like electronics, but has the advantage of worker training programs. US and German productivity slowed with the decline in global innovation. Japan lags behind US service sector productivity. Its manufacturing industries set the productivity frontier in the 1990s but have since fallen behind. Japan has low productivity small firms and lacks effective competition.

Economic growth provides broad and substantial benefits. When growth is strong, household incomes rise, and wages increase; it becomes much easier to balance budgets and to meet the needs of the poorest members of society. While overall economic growth does not guarantee that everyone in an economy will be better off, it is the single most important source of improvements in economic welfare.

Strong economic growth, in turn, comes from two sources, the growth in the workforce and growth in labour productivity.[2] The demographic trend in advanced economies has been towards lower birth rates leading to slower growth in the population and labour force (Table 1). An aging of the population compounds that trend as more workers move into retirement; and while immigration can provide an offsetting source of growth, it often generates social stresses and political resis-

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2 In this article labour productivity is measured by output per worker hour. That means changes over time in hours worked per worker will also impact output growth. There have been reductions in hours worked per worker, especially in Germany and Japan.

Table 1: Labour Force, Total Hour, Output and Labour Productivity in Advanced Economies (average annual rate of change)

	1970-1995	1995-2004	2004-2018	Change from 1970-95 to 2004-18
Labour Force				
Japan	1.0	0.0	0.2	**-0.8**
Germany	1.5	0.2	0.6	**-1.0**
United States	1.9	1.2	0.7	**-1.2**
G7	1.3	0.8	0.6	**-0.7**
Total Hours				
Japan	0.1	-1.0	-0.1	**-0.2**
Germany	-0.4	-0.3	0.7	**1.1**
United States	1.6	0.9	0.7	**-0.9**
G7	0.6	0.4	0.5	**-0.1**
GDP per hour (2015 constant prices)				
Japan	3.8	2.1	0.8	**-3.0**
Germany	2.9	1.5	0.9	**-2.1**
United States	1.5	2.5	1.1	**-0.3**
G7	2.4	2.2	0.9	**-1.5**
GDP (2015 constant prices)				
Japan	3.9	1.1	0.7	**-3.2**
Germany	2.5	1.3	1.5	**-0.9**
United States	3.1	3.4	1.9	**-1.2**
G7	3.0	2.5	1.5	**-1.6**

Source: Calculations based on OECD Stat data.

tance. Slower labour force growth leaves productivity as the main driver of overall economic advancement and, unfortunately, it too has slowed. Table 1 highlights a pervasive pattern of slower growth in in the workforce and labour productivity in the high-income economies of the OECD. Productivity improvement has been slow in the United States since the early 1970s, except for a period of resurgence in the late 1990s and early 2000s. Germany and Japan had faster growth through the 1970s, but their growth rates have also fallen sharply.

A comparison of the patterns of productivity growth in the three largest mature economies, the United States, Japan, and Germany, is the focus of this article. They are representative of the productivity frontier in their respective regions.[3] They also have comparable high-quality data on the growth of output, labour, and capital at the level of the total economy and individual industries. We will use that data to examine productivity changes in the three economies in the aggregate and subsectors. Looking at the three most important mature economies can cast light on the nature of the slowdown and provide a step towards disentangling the causes of the slowdown. There have been many efforts to understand why growth has been so slow in recent years, and while there is some suggestive and interesting evidence of what factors may be at work, there is no con-

3 We do not include China, even though it is now the largest economy in the world based on purchasing power parity (PPP). China is still a middle-income country whose growth is driven by a different phenomenon of raising overall productivity by shifting the workforce out of agriculture into industry and services and adopting (copying) technologies in standard use in higher productivity countries.

sensus explanation for the pattern of slow growth that is widespread both by country and by industry (Baily and Montalbano, 2016; Gordon and Sayed, 2019; and OECD, 2019a).[4] Another motivation for this line of research is that the cross-country comparisons may be helpful in identifying industries that have the potential for faster growth in the future.

The article proceeds as follows. In the first major section, we provide a background on productivity definitions and measurement approaches. In the second section, we report productivity results for the aggregate economy, industrial sectors, and manufacturing industries for Japan, US, and Germany. We then identify and analyze problem industries and draw on results from previous research. We conclude with a discussion of reasons for respective productivity performance in the three economies.

Benchmarking to Find Industries Where There is Potential for Faster Growth

Which industries have performed particularly poorly relative to past rates of growth or relative to the performance of similar industries in the comparable economies? Even though the slowdown is pervasive, it may be possible to identify industries where faster growth is possible. Policy may be able to facilitate faster growth, for example by encouraging capital investment, or technology innovations (R&D). Changing the regulatory environment may also result in stronger competition and restructuring that improves productivity.

The first strategy to identify industries with greater growth potential comes from looking at industry growth rates. If productivity growth has been negative for a period of years it is important to ask what is causing this regression of productivity. Another sign of the possibility of faster growth potential is an industry that experienced rapid growth in a past period but has slowed more recently. Has the past growth exhausted the possibilities for faster growth in the future, or is there potential for another wave of growth?

A second strategy for finding industries with greater growth potential makes use of a comparison of productivity levels across countries. Industries that have productivity levels below those of comparable countries have the potential to catch up. With total factor productivity, productivity convergence will occur as technologies and best business practices are diffused across countries. With labour productivity, greater capital investment can bring lagging industries up to, or closer to, the productivity frontier. This second approach is important because it provides a possible way to improve productivity that avoids debate about whether future innovations can foster faster growth. If another country has already achieved higher productivity, then the challenge is to find a way to adopt technology already in use. This approach is

4 There is an extensive literature on the slowdown. Other articles in this area include Andrews *et al.* (2016), Askenazy *et al.* (2016), Furman and Orszag (2018), and Gutierrez and Phillipon (2017).

particularly important for Japan which lags in overall productivity.

A caveat to the argument is that there may be natural barriers to achieving a higher productivity level in some economic activities[5]. Silicon Valley is hard to replicate. The United States also has advantages in its endowment of arable land and energy resources. Managers may be less skilled in some countries than in others. This caveat should not be overstated. As we have known since David Ricardo, differences in endowments can lead to differences in specialization and trade rather than the perpetuation of low productivity industries. Managers are mobile, indeed many of the best US CEOs come from other countries, or their parents did. Foreign direct investment (FDI) can bring proprietary technology or best practice business processes into a country.

Definitions of Productivity

In this article we use both labour productivity, calculated as real value added per hour worked, and total factor productivity (TFP). The measure of TFP, drawn from the OECD STAN database, is real value added per unit of combined capital and labour. We also take the TFP estimates provided to us by Jorgenson, Nomura and Samuels (2018) that use gross output per unit of combined capital, labour, energy, service inputs and materials.

An advantage of labour productivity at the aggregate level is that it links GDP growth and wage growth. GDP growth is roughly the sum of the growth rate of GDP per worker and growth in the number of hours worked (employment growth adjusted for changes in hours per worker). Growth in output per hour in the business sector is closely linked to the growth of real labour compensation.[6] In this analysis of labour productivity, we have mostly relied on a value-added concept of output, and the labour input is defined as the hours of all workers. The advantage of TFP is that it estimates the shift in the production function as a result of technological change and other improvements in production methods. Since we do not estimate the impact of changes in human capital directly, those are also included in TFP.

If output is measured at the aggregate level, or if it is measured by value added at the industry or firm level, there are only two inputs to production, capital and labour.[7] In that case, the growth rate of labour productivity (output per hour) is the sum of the growth of TFP plus the con-

5 The levels of productivity are compared in a single base year using PPP exchange rates for that year to translate outputs and inputs in euros or yen into dollars. (labour input is measured in worker hours). Productivity in each country then changes in years away from the base year according to real output and input changes relative to the base year. In other words, productivity levels are set in one single year and then each country's relative industry or aggregate productivity growth rates determine the levels away from the base year.

6 Exceptions to this pattern can result for changes in the aggregate share of labour compensation, variations in its distribution, or divergent price deflators for output and compensation (Sharpe and Uguccioni, 2017).

7 We have chosen not to adjust the labour input for quality changes. The available data suggest that labour quality, as measured by educational attainment, changes only slowly over time and has not been a major factor in the recent productivity slowdown. There are also unsettled issues about how to best adjust for labour quality.

tribution of capital deepening (the increase in capital per hour worked weighted by the share of capital in cost). This is a valuable decomposition, indicating whether, say, a decline in labour productivity growth stems from a drop in TFP growth or a decline in the contribution of capital.

Comparing levels of productivity across countries requires a way to compare output measured in different currencies. Sometimes foreign exchange rates are used for this purpose and that may work well to compare tradable goods. However, exchange rates fluctuate over time in ways that can give a distorted picture of relative productivities and many goods and most services are not traded. The approach favored by the OECD and others is to measure purchasing power parity (PPP) exchange rates to capture relative prices of comparable goods or services across countries. Finding accurate price comparisons and insuring comparability of products is a challenge and there are differing findings depending on how the comparisons are made. Taking account of taxes is one of the more difficult aspects of this task along with ensuring comparable quality of goods or services. Also, the price comparisons are typically made in a single year and then the PPP exchange rate is extrapolated to other years using relative industry price changes in the countries being compared. There is room for error in these comparisons. We use PPPs estimated by the University of Gröningen for Germany and Japan comparisons to the United States and we also use the PPPs for Japan developed by Jorgenson, Nomura, and Samuels (2018).

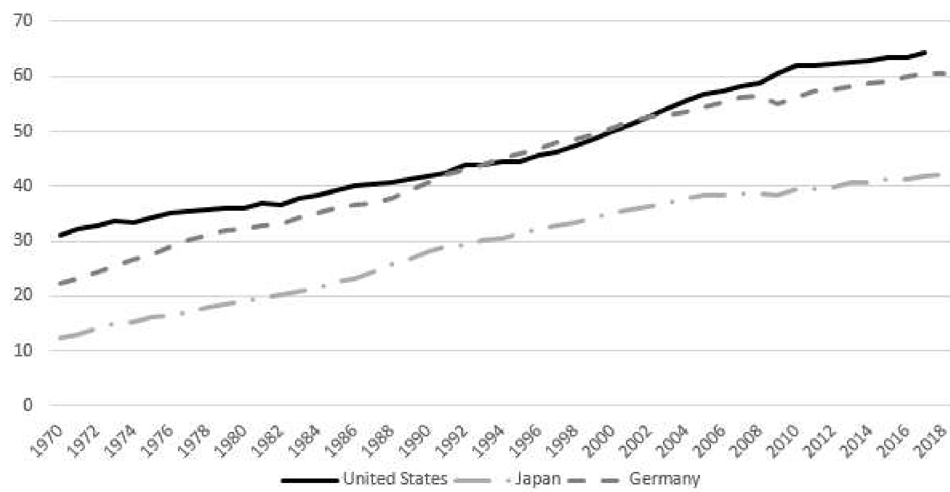
Productivity at the Aggregate Level

Chart 1 shows labour productivity at the aggregate level (GDP per hour worked) for Germany, Japan, and the United States from 1970 until the present, based on OECD data using purchasing power parity exchange rates for 2010. In 1970, both Japan and Germany had productivity levels that were only a fraction of the United States, but in subsequent years productivity growth was much higher and they reduced the gap[8]. Germany reached the US level of output per hour by the early 1990s and moved ahead of the United States briefly, before falling slightly behind at the end of the period. However, Germany has greatly reduced the number of hours worked per worker and so output per worker was only 73.7 per cent of the US level in 2017.

Japan also moved closer to the US productivity level before its financial crisis of the early 1990s. Subsequent growth has been slow, and the level of productivity remains well below that of the United States and Germany at the end of the period. Changes in hours worked per worker were also important in Japan. Historically, Japanese workers spent much longer at work than did American workers but over time this gap was reduced, and the hours per worker were similar in the two

8 The levels for 1970 for the three countries are as follows: United States: $30.9 US, Germany: $22.3 US, Japan: $12.5 US. Hence, Germany's aggregate productivity level was 0.72 relative to the United States in 1970, and Japan's aggregate productivity level was 0.40 relative to the US level in 1970.

Chart 1: GDP per Hour Worked in Japan, Germany and the United States, 1970-2018 (USD, constant prices, 2010 PPPs)



Source: OECD Stat

countries in 2018 based on OECD data.

A major theme of the economic growth literature of the 1970s and 80s was the "catchup hypothesis".[9] Regression analyses and growth theory suggested that the speed of productivity growth of a country depended on how far away it was from the productivity frontier, defined in most industries by the United States. Japan and Germany grew very rapidly indeed in the 1960s into the 1970s, as did some other countries. Paul Romer (1986) cast doubt on convergence by showing that if you include all the countries in the world, there is no systematic tendency for countries below the productivity frontier to catch up to the leaders. Romer argued that most countries did not have the technology needed to converge to the frontier. One can also argue that many countries lack the legal framework and market institutions to support catchup, and some do not have a workforce with the necessary skills and education. Subsequent empirical research on cross-country growth has found that catchup growth remains important even when looking at a broad sample of countries, but only after controlling for other growth determinants–conditional convergence (Barro and Sala-i-Martin 1998).

The data in Chart 1 are consistent with the story of catchup growth in both Japan and Germany in the years after World War II, some of it surely coming from postwar recovery and some from the diffusion of best-practice methods and technologies from the United States. By the 1990s, Germany had completed this catchup pro-

9 A good exploration of catchup is in Baumol, Batey Blackman, and Wolff (1989). An extensive bibliography is included in this book.

Table 2: **Contribution from TFP and Capital Deepening to Labour Productivity Growth in the United States, Germany and Japan (average annual per cent or percentage point change)**

	1985-1995	1995-2004	2004-2018
United States			
Labour Productivity	1.3	2.5	1.1
TFP	0.7	1.5	0.5
Capital Deepening	0.6	1.0	0.6
Japan*			
Labour Productivity	3.3	2.1	0.8
TFP	1.6	0.7	0.5
Capital Deepening	1.7	1.3	0.3
Germany			
Labour Productivity	2.5	1.5	0.9
TFP	1.6	0.8	0.6
Capital Deepening	0.9	0.7	0.3

Source: Calculations based on OECD Stat data. Labour Productivity is measured as value added per hour worked.

*Japan's last period is 2004-2017.

cess, and the level of aggregate labour productivity in the United States and Germany has been roughly the same for several decades. Japan, on the other hand, did not complete the catchup process and in recent years the gap has widened. An important puzzle is why Japan has not completed the catchup process. Japan is a mature economy that should have been able to converge to the productivity frontier. Indeed, as we show below, many Japanese industries did catch up or even set a new frontier but other industries still lag behind, as does the overall economy.

The productivity growth slowdown

Table 2 shows the pattern of both labour and total factor productivity growth for the three economies from 1985 through 2018, broken down into three time-periods.[10] As shown in the top panel, labour productivity growth in the United States was a modest 1.3 per cent a year from 1985 to 1995 split almost evenly between the contribution of TFP and the contribution of capital deepening. There was then a sharp acceleration, lasting about a decade, largely driven by faster growth in TFP, but there was also a greater rate of capital deepening. The post-2004 slowing of overall growth is evident in much smaller contributions from both capital deepening and TFP.

The second panel repeats the same calculations for Japan, where labour productivity growth was much more rapid than in the United States in 1985 to 1995 (catching up), but growth slowed in the second period and fell further to just under 0.8 per cent a year in the final period. Capital deepening and TFP both slowed sharply after 1995.

The same calculations for Germany are shown in the third panel and reveals a

10 The OECD data used here start in 1985 and end in 2018.

pattern similar to Japan. The three panels of Table 2 highlight the extent of the labour productivity growth slowdown in all three economies with a strong common element of very slow productivity growth since 2004. Both TFP and capital deepening contributed to growth over the full time-period, and there was a slowing in both elements after 1995. As in Japan and Germany, the contribution of capital deepening after 2004 was very small.[11]

Growth in TFP and the contribution of capital are connected. If technological change slows down, as reflected in slower TFP growth, it results in slow labour productivity directly, but it also reduces the incentive for businesses to invest. Alternatively, if some other factor causes a decline in investment, such as the global financial crisis, this may lead to a lower pace of TFP growth because newer technologies are often embedded in the new capital. The magnitude and pervasiveness of the growth slowdown suggests both causal effects have been at work.

The United States is notable for the sustained nature of its economic recovery from the 2009 recession that lowered the unemployment rate to historical lows. It received additional stimulus from a 2017 reduction in business taxes that was intended to encourage investment. While the tax cut contributed to continued growth in final demand and employment, there has been little evidence of a major impact on productivity growth, which continued at the average of the post-2004 period. As this is written, the Covid-19 virus has disrupted all economies and it will be some time before the underlying productivity growth trend is visible.

Productivity Growth by Broad Industry Category

Consistent labour productivity and TFP data by industry are available from the OECD Structural Analysis (STAN) database for the United States, Japan, and Germany. Japanese data are available from 1995 through 2016 but we have used data from the Japan Industrial Productivity (JIP) database to extend the sample back to 1991. We did not take the data back prior to 1995 for Japan for agriculture and construction because there was a wide discrepancy between the STAN data and the JIP data where they overlap.

Table 3 shows the results for labour productivity (value added per hour worked) for the three countries. The slowdown of productivity growth after 2004 has been widespread and easily visible in the industry data for all three countries. In Japan, there are only two industries, construction and real estate, that show faster productivity growth after 2004. Over the full period 1991 through 2016 for the business sector, labour productivity grows about a half percentage point faster in the United States than Japan and Germany. This is the result of faster growth prior to 2004, especially from 1995 through 2004. From 2004 through 2016, the annual rates of growth

11 A referee pointed out to us that Japan and Germany may have overinvested prior to 2004, which would have led to lower investment subsequently.

Table 3: Labour Productivity by Industry, United States, Japan, and Germany (average annual rate of change)

		United States				Japan				Germany			
		1991-1995	1995-2004	2004-2016	1991-2016	1991-1995	1995-2004	2004-2016	1991-2016	1991-1995	1995-2004	2004-2016	1991-2016
1	Agriculture, forestry and fishing	1.3	5.8	3.4	3.9	-	2.0	1.4	1.7*	-5.2	7.6	-1.0	1.4
2	Mining and quarrying	8.0	-0.3	2.2	2.2	-6.4	4.0	-7.1	-3.0	7.2	-0.6	2.2	2.0
3	Manufacturing	3.6	6.1	1.9	3.7	2.7	3.3	2.4	2.8	3.2	2.9	2.0	2.5
4	Utilities	1.3	0.5	-0.7	0.0	0.7	2.5	-3.5	-0.7	1.0	3.1	0.6	1.6
5	Construction	0.6	-0.7	-1.1	-0.7	-3.2	-1.2	0.9	-0.5	-1.0	0.5	0.1	0.1
6	Wholesale and retail trade	3.6	5.1	1.0	2.9	5.0	2.0	0.4	1.7	0.6	2.9	1.8	2.0
7	Transportation and storage	1.1	1.6	-0.1	0.7	1.4	-0.3	-0.8	-0.3	4.3	3.6	0.6	2.3
8	Information and communication	1.6	4.1	3.9	3.6	7.9	5.5	-0.2	3.2	5.3	4.7	3.4	4.2
9	Financial and insurance activities	1.6	4.1	1.3	2.4	0.6	1.1	0.3	0.6	1.3	-2.0	1.1	0.0
10	Real estate	3.4	0.7	2.0	1.7	-	1.6	0.3	0.9*	2.0	1.6	1.3	1.5
11	Professional, scientific and technical activities; administrative and support service activities	-0.7	1.5	0.6	0.7	2.7	3.8	1.7	2.6	0.2	-1.7	-1.3	-1.2
12	Community, social and personal services	-0.7	-0.2	0.1	-0.1	0.5	-0.1	-0.5	-0.2	1.8	0.6	0.4	0.7
	Non-agriculture business sector excluding real estate	**2.0**	**3.4**	**1.1**	**2.1**	**1.8**	**2.2**	**1.0**	**1.6**	**1.7**	**2.0**	**1.2**	**1.5**

Source: Calculations based on OECD Structural Analysis statistics (STAN). The growth rates shown for the private nonfarm business sector exclude agriculture and construction for all three countries. They differ from the data shown in Table 2, which are based on total GDP.

Note: 1995-2016 for starred industries in Japan.

are very similar in all three countries: 1.1 per cent in the United States, 1.0 in Japan and 1.2 per cent in Germany.

Looking at the results by industry reveals that all three economies saw declines in manufacturing productivity growth after 2004, but the decline is much sharper in the United States. This is partly the result of the ending of the surge in computer and semiconductor productivity in the 1990s and early 2000s, a surge that slowed after 2004. This industry has also moved large portions of its production overseas, making it a smaller fraction of manufacturing. Post-2004, Japan's manufacturing productivity growth rate has been the greatest, followed by Germany.

Productivity growth in wholesale and retail, as well as transportation and storage, has also been very slow in all three countries since 2004. The story of faster growth in earlier periods is now well-known as big box retailers and franchised smaller establishments displaced traditional retailers and integrated the wholesale function into their retail operations (Lewis *et al.*, 2001). Online retail is now changing the industry, but as yet this segment is not large enough to offset the decline in growth in bricks and mortar retailing.

The information and communications industry consists of publishing and broadcasting, telecommunications, information technology (including computer programming consultancy) and information service activities. This sector has benefit-ted from advances in electronics and shows rapid growth in all three economies. Over the full period 1991-2016, the productivity gains were substantial across the three economies, but growth came to an abrupt end in Japan after 2004.

Productivity growth in the utilities industry has been very weak in the United States and Japan, zero in the former and negative in the latter over the full 1991-2016 period. In contrast, growth in Germany has been 1.6 per cent a year over the whole period, with rapid growth concentrated in 1995-2004. Utilities are heavily regulated in all three countries and have been impacted by shifting fuel prices and environmental concerns. Both Germany and Japan have shut down nuclear plants while the US industry has taken advantage of cheap natural gas. Growth slowed in Germany after 2004, but it turned negative in the United States, a puzzling result likely to be a consequence of regulation.

Financial and insurance activities in the United States have seen relatively strong productivity growth over the full period, with the strongest growth in 1995-2004, a period that included the early years of the real estate boom. Growth slowed after 2004, but still did a little better than in the other two economies. All three countries were impacted by financial cycles. The measurement of productivity in this industry is also difficult and the results should be viewed with caution.

Labour productivity growth in agriculture, forestry and fishing[12] has been much more rapid in the United States over the full time-period at 3.9 per cent a year, compared to 1.7 per cent in Japan[13] and 1.4 per cent in Germany. There is substantial volatility in the growth rates over shorter periods, which partly reflects weather patterns. Over the entire postwar period, productivity growth in US agriculture has been among the most rapid of all US industries, driven by advances in seeds, fertilizers, irrigation and other techniques. It may be that climate change will impact this industry in all three countries, but that is not yet evident in the productivity data through 2016.

Mining and quarrying saw good productivity growth in the United States and Germany but a decline in labour productivity in Japan. This industry is impacted by the depletion of the natural resource base, by the offsetting development of new technologies for extraction, and by regulation. In the US data, the period of fastest growth is prior to 1995. The fracking revolution is not yet evident in the most recent time-period.

Productivity in the remaining industries—real estate, professional services and community services—is difficult to measure and it is hard to see clear patterns in the reported data. The real estate boom and bust in the United States does not show up strongly in the productivity

12 Since agriculture is by far the most important part of the sector, the agriculture, forestry, and fishing industry will be henceforth referred to as the agriculture industry.

13 The STAN data for Japan are only available from 1995 to 2016.

14 http://www.csls.ca/ipm/38/Baily_Appendix.pdf.

growth data.

Table A1 in the on-line Data Appendix to this article[14] shows the comparable industry findings for total factor productivity. The TFP results are similar to those for labour productivity, particularly in showing the slowdown in growth after 2004. There are some differences, however. In Germany, the aggregate slowdown in TFP is very mild overall, and several industries—mining, construction (by a tiny amount), financial services, and professional services (a smaller TFP decline)—have stronger TFP growth after 2004. Community, social and personal services stay the same, while manufacturing's slowdown is modest. In the United States, the TFP slowdown is largest in agriculture and manufacturing. Mining, real estate, professional services, community, social and personal services all show somewhat faster growth after 2004, and construction has a slightly smaller rate of decline. In Japan, the post-2004 slowdown remains pronounced with a pattern of change similar to labour productivity.

Manufacturing Productivity

There is more industry detail available for the manufacturing sector than for service industries. The United States, Japan and Germany have the largest manufacturing sectors among developed economies, and we have seen the importance of manufacturing to the overall slowdown in productivity growth. It is worth looking in more detail at the manufacturing industries. Table 4 shows the labour productivity growth rates for the manufacturing sub-industries as given in the STAN data, basically 2-digit industries except that machinery is broken into electrical, electronic and optical equipment and machinery and equipment n.e.c. The comparable TFP growth figures are given in Appendix A2.[15] The data for Germany also ends in 2015, compared to 2016 for Japan and the United States, and there is no STAN data for Japan prior to 1995.

The data for Germany show relatively steady growth across the sub-industries within manufacturing over the full period from 1991 to 2015, although with a broad slowdown after 2004. To qualify this statement: machinery n.e.c. growth is negative after 2004, while food products and transportation equipment have faster growth after 2004, both in labour productivity and TFP (Table A2 in the on-line A Data Appendix). Even with these qualifications, it appears that German manufacturing companies have been able to improve operations year by year across a broad range of industries. There are not periods of very rapid growth (as in the United States in the 1990s). Post-2004, labour productivity growth and total factor productivity growth in Germany are the same, indicating very weak capital investment.

The United States and Japan had faster growth than Germany over the full period, with particular contributions from electrical and electronic equipment (which includes computers). The US sector has not seen consistent growth in other manufac-

15 The coke and refined petroleum industry is missing from the Germany panel because separate STAN data are not available for Germany.

Table 4: Labour Productivity in Manufacturing Industries in the United States, Japan, and Germany (average annual rate of change)

		United States				Japan			Germany			
		1991-1995	1995-2004	2004-2016	1991-2016	1995-2004	2004-2016	1995-2016	1991-1995	1995-2004	2004-2015	1991-2015
3a	Food, beverages and tobacco	4.6	-0.8	-0.1	0.4	-0.1	0.0	0.0	-0.9	-0.5	1.7	0.4
3b	Textiles, wearing apparel, leather and related	3.5	4.2	1.2	2.6	-0.5	0.3	-0.1	5.8	3.4	0.9	2.6
3c	Wood and paper , and printing†	-3.1	2.2	1.3	0.9	0.6	0.1	0.3	2.3	2.7	2.3	2.5
3d	Coke and refined petroleum	5.1	13.2	-1.0	5.1	-0.3	-0.9	-0.6	-	-	-	-
3e	Chemical and pharmaceuticals	3.0	3.9	0.9	2.3	2.5	1.5	1.9	8.1	4.7	0.9	3.5
3f	Rubber and plastics	1.4	4.7	0.3	2.0	-	-	-	4.5	2.3	1.3	2.2
3g	Other non-metallic minerals	3.1	2.0	-0.1	1.2	2.7	-0.3	1.0				
3h	Basic metals and fabricated metal products	2.3	2.7	0.4	1.6	0.9	0.3	0.5	3.2	2.4	0.7	1.8
3i	Electrical, electronic and optical equipment	14.6	15.5	6.9	11.2	10.4	7.3	8.7	3.7	5.6	3.7	4.4
3j	Machinery and equipment n.e.c.	0.1	2.0	0.5	1.0	1.8	3.1	2.6	3.9	1.6	-0.7	0.9
3k	Transport equipment	0.2	4.1	2.3	2.6	2.1	0.5	1.1	1.3	1.4	4.5	2.8
3l	Furniture; other manufacturing	0.7	3.7	1.3	2.1	-	-	-	2.0	3.4	0.7	1.9
	Manufacturing	**3.6**	**6.1**	**1.9**	**3.7**	**3.3**	**2.4**	**2.8**	**3.2**	**2.9**	**1.9**	**2.5**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

†Paper and paper products for Japan.

turing industries, and has had very slow growth since 2004. The story for Japan has been similar, with strong productivity growth in electrical and electronics and not strong growth elsewhere. Labour productivity growth and TFP growth in manufacturing in Japan have been faster than in the United States and Germany since 2004.

We turn now to the additional information that can be learned from using productivity levels as well as growth rates.

Problem Industries Identified Using Productivity Levels and Growth Rates

One means of diagnosing industries with a productivity problem is to focus on those where the level of productivity is below the frontier but where catch up is not occurring. Specifically, we will identify German and Japanese industries that were below the productivity level of the US industry (measured in PPP values) in 1994, but where the productivity growth rate 1995-2016 has been slower than in the United States. US industries with a similar problem can also be observed if their level of productivity was below either Japan or Germany but where the US industry was growing more slowly.[16] If there are "problem" industries, the next step is to identify

16 Studies from the McKinsey Global Institute used the approach of flagging industries with productivity below the level of the frontier industry. The methods are described in Baily and Solow (2001). The McKinsey studies generally did not look at productivity growth rates, however.

what the barriers are to industries achieving frontier-level productivity. In some cases, there may be a natural barrier as we noted earlier in this article. However, if the barrier to high productivity is the result of inefficient regulation, or problems in technology development, or lack of skills, or some other policy lever or constraint, then better future performance may be possible. The first step, therefore, is to identify lagging or problem industries.

Lagging Industries

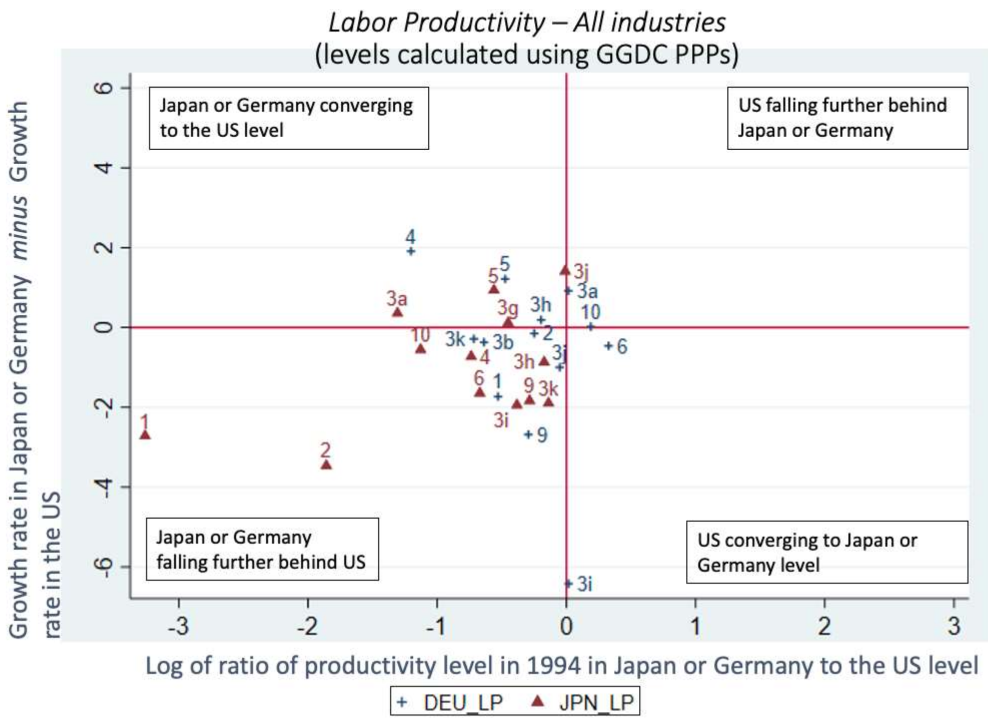
Using the results already presented for industry labour productivity growth rates, we calculate the rate of growth of each industry in Japan and each industry in Germany over the period 1995-2016 and compare it to the growth rate in the same industry in the United States. These growth-rate differentials are plotted on the vertical axis of the charts below, and the zero line indicates the same growth rate in two comparison countries. A positive number for the industry in either Japan or Germany means it grew faster than the US industry from 1995-2016. That may be a red flag for the US industry. A negative number is where the industry is growing more slowly than in the United States, implying a possible problem industry for either Japan or Germany or both.

On the horizontal axis of the chart, we plot the natural logarithm of the ratio of the level of labour productivity in Japan or Germany to the level of labour productivity in the United States. The comparisons of productivity levels are based on industry-specific PPPs for 1997 from the Gröningen Growth and Development Project (GGDC), which are then linked to our prior industry-level measures of labour productivity growth from the OECD (Tables 3 and 4). If the PPP-adjusted levels of labour productivity are the same in two countries, then the ratio is unity and log value is zero—this is the vertical axis in the figure. Points to the right of the zero axis line show industries where labour productivity was higher in either Japan or Germany relative to the United States in 1994. Points to the left show industries where productivity was higher in the United States.

The horizontal and vertical axes divide the industries into four quadrants. The upper left quadrant is where the US productivity level was higher, but growth was faster in Germany or Japan. This case indicates that the industry in Japan or in Germany was behind the US level of productivity but catching up—there was convergence to the US frontier productivity level. The lower right quadrant is where the US productivity level is lower than in either Germany or Japan but where the US industry is catching up. Thus, both the upper left and the lower right quadrants are consistent with the convergence hypothesis, where the industry that was below the frontier level of productivity was also catching up to the frontier.

The industries in the lower left quadrant or in the upper right quadrant are not converging to the frontier level of productivity among these three countries. These are industries that were below the most productive industry in 1994 but were falling further behind 1995-2016. The lower left quadrant is for problem industries either in

Chart 2: Industry Productivity Growth Differentials (1995-2016) against Productivity Levels (1990) Relative to the United States, Japan and Germany (All Industries, labour Productivity)



Source: Calculations based on GGDC PPPs and OECD STAN data.

Note: Major industry labels in table 3. Manufacturing industry labels (subpart 3) in table 4.

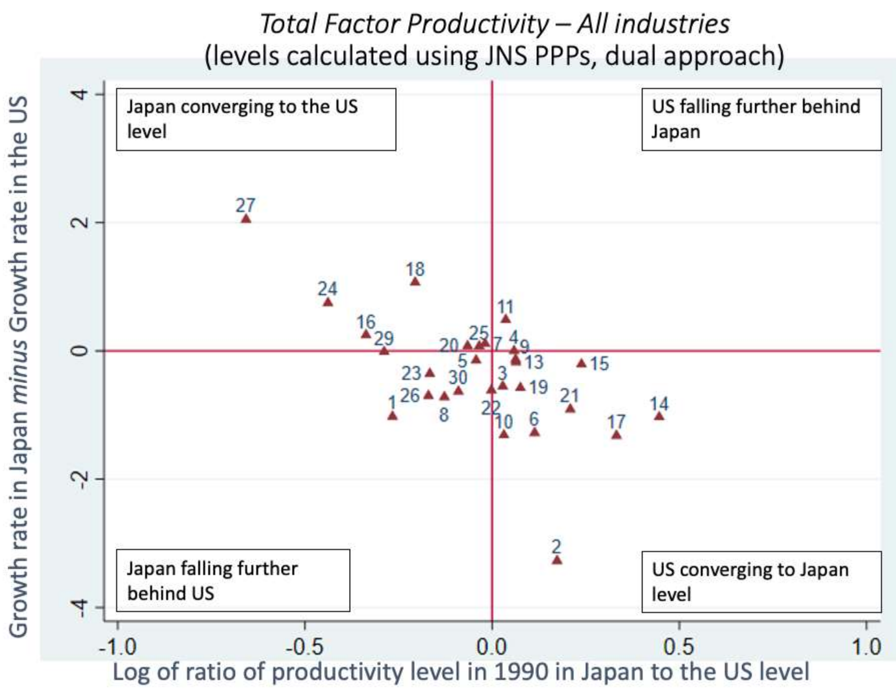
Japan or Germany. The upper right quadrant identifies problem industries in the US, industries that were below level of productivity in either Japan or Germany but were also growing more slowly.

Chart 2 shows the industry plots for manufacturing and non-manufacturing industries in the STAN data base. Industries in Japan are shown as triangles and industries in Germany as plusses. The observations are labeled with the industry numbers of Tables 3 and 4 for identification purposes. The labels 3a, 3b, etc., indicate manufacturing subindustries which are listed in Table 4.[17] The figures reveal that labour productivity in most industries in both Japan and Germany were computed to be below the level of productivity in the United States in 1994 (most points are to the left of the zero line). Some of the industries are in the upper quadrant, indicating they grew faster than the United States industry over the period 1995-2016 (they were converging), but many are in the lower quadrant, indicating they fell further behind.

In Germany, agriculture, finance and textiles are below the US level and falling

17 Even though they are in Table 4, they are part of manufacturing, which is industry 3, hence they are 3a, 3b and the rest.

Chart 3: Industry TFP Growth Differentials (1991-2016) against Productivity Levels (1990), Japan Relative to the United States



Source: Calculations based on JNS data.

Note: This chart is based on relative levels in 1990, rather than in 1994 as in the previous chart. Industry labels in Table A3 in the on-line Data Appendix.

behind. The same is true of transport equipment but that may be deceptive because the US industry includes aerospace. The German auto industry is very strong. Productivity in electrical and electronic equipment was on a par with the United States in 1994 but grew much more slowly after that. Germany is catching up in utilities and construction. Germany is ahead of the United States in trade but the United States is catching up. The food and beverage industry in the United States was on par with Germany in 1994, but grew more slowly post-1994.

Turning to Japan, there are many industries that are below the US level of productivity and falling behind. Agriculture and mining are way behind. Utilities, trade, finance are also falling further behind. Among manufacturing industries, these data suggest basic metals, electrical and electronic equipment, and transport equipment are also falling further behind.

Productivity Level and Growth Results from Jorgenson, Nomura and Samuels

A 2018 study by Jorgenson, Nomura and Samuels (JNS) developed their own matching industry-level production accounts for the United States and Japan covering 36 industries from 1955-2015. They also constructed a greatly expanded set of PPPs for 174 industries using unpublished EU-OECD data, a Japan-US bilateral input-output table, and a Japanese survey comparing domestic and foreign prices.[18] JNS calculated their own productivity growth rates and levels for 36 industries in Japan. Although their data are proprietary, they have generously made them available. Since their analysis is structured around TFP estimation we have plotted the comparable figure to those shown in Chart 2 in terms of TFP, as shown in Chart 3.[19] The industry labels for this figure are shown in the Appendix Table A3.

Unlike the prior results, the JNS TFP data show strong evidence of convergence with 64 per cent of the industries falling in the upper left quadrant or the lower right quadrant. The JNS figures for TFP also show many industries where the United States was behind Japan at the start of the period (in 1990), all of them manufacturing sub-industries. All but two of these converged towards Japan over the period from 1990 to 2015. Despite the general pattern of convergence, there are six industries in Japan that were behind the United States in 1990 and fell further behind subsequently. These were agriculture, furniture, water transport, textile, finance and insurance, and other transport and storage.

In addition, mining, apparel, printing, primary metal and computer and electronic products started above the United States in 1990 but fell below by 2015. This is concerning for Japan, and furthermore, when the level of TFP in Japan was higher than in the United States in 1990, there is, on average, a decline in TFP growth over the subsequent period, 1990-2015. US industries in the lower right quadrant in the figure are catching up to Japan but this is happening in large part because of weak Japanese performance in industries that had been productivity leaders in 1990.

We also used the JNS data to calculate labour productivity for their industries, based on value added per hour worked. There is less convergence in the labour productivity estimates, which is surprising since capital accumulation has been seen in the literature as an important way in which convergence occurs to equalize labour productivity levels as countries develop. The lack of convergence in labour productivity surely reflects weakness in capital accumulation in Japan 1990-2015.

Reasons for German Productivity Performance

Influential economist Hans Werner Sinn (2006) has argued that Germany is (or was) the "laggard of Europe" and he describes Germany as a "bazaar" economy in which German companies produce goods in Eastern Europe, bring them back to Germany, add a prestige nameplate and then re-export them, earning high markups. If correct, this behavior would have under-

18 Details on the data calculations are provided in Jorgenson, Nomura, and Samuels (2018). Unfortunately, the data do not exist to extend the methodology to Germany.

19 JNS calculate TFP levels from gross output adjusting for all inputs, capital, labour, energy, materials and purchased services. This results in estimates of TFP growth that are smaller, scaled differently, than estimates from value added. That scaling difference does not impact the lessons to be learned from TFP performance. In their work, JNS provide productivity data back to 1955, however, the focus of this report is on more recent data and we will look particularly at the results from 1990 to 2015.

mined Germany's traditional strength in manufacturing. A few years later, Dustmann *et al.* (2014) argued that Germany had moved from sick man of Europe to superstar. They show the share of domestic value added in German manufacturing output has not declined in the way claimed by Sinn (2006).

There is greater agreement in the literature that German productivity growth has been weak, but there are a variety of explanations given for this. Elstner, Feld, and Schmidt (2016), in a report from the German Council of Economic Experts, argue that the main reason for slow productivity growth is that Germany has absorbed over three million workers since 2005, mostly from Eastern Europe and possessing comparatively low skill levels. They also argue that restructuring of value chains in manufacturing has come to an end. The 2016 OECD survey of the German economy also mentions the effect on productivity of integrating immigrants into the workforce. In addition, the OECD points to concerns about regulation, especially in services. Professional services, they say, are almost completely closed to outside competition. Schneider (2013) also points to the low productivity in the corporate services sector.

A study by the McKinsey Global Institute (2002) also stressed the role of regulation in depressing productivity in Germany and limiting competition, particularly in services. Regulation in Germany or in the EU also prevented some companies from achieving optimal scale.

Both Schneider and the OECD identify the low level of capital accumulation in Germany as a cause of weak labour productivity growth. Van Ark *et al.* (2009) point to concerns about the lack of accumulation of intangible capital in Germany. Low investment is only a proximate cause of productivity weakness and it is important to determine why companies are not investing at a higher rate.[20]

Van Ark, de Vries, and Erumban (2019) examine the contribution to productivity in the EU and in the United States from the production and use of digital technology, dividing the using industries into those that use the technology intensively and those that do not. They suggest a connection between digital technology and productivity growth for both regions, but their results for Germany do not indicate such a connection. They report (in Table 2 from their article) that the biggest contributions to the growth in German GDP per hour came from the *least* intensive digital-using industries both in the period 1996-2006 and in the period 2007-17.[21] The United States does show a connection between productivity growth and digital technology, so the two countries are different in this regard.

Takeaways for German Productivity Performance

In three industries, utilities, construc-

20 The McKinsey study (2002) reported that some German companies report that investing in additional capital (including IT capital) would not payoff because regulation prevented them from adjusting labour inputs.

21 Further, the decline in GDP per hour worked between 1996-2006 and 2007-17 occurred across all three industry types (the digital producing industry and the two using industries).

tion, and textiles, the German productivity levels are behind those in the United States but are catching up. Productivity growth in utilities since 2004 has been poor, but not as bad as in the United States. The industry is regulated, and Germany has committed to improving its emissions levels, but the transition is proving costly (Deloitte, 2015). Construction productivity growth has also been bad in all three countries. This is also the effect of regulation, plus measurement problems may be causing an understatement of growth. The textile industry in Germany uses high technology to compete globally whereas the US industry has largely migrated overseas leaving behind a specialty industry with high relative productivity (Int-Team Consulting, 2015).

Two German industries are falling further behind. Policy makers must decide the extent to which they wish to preserve agriculture at its current scale at the price of a significant productivity penalty. Similarly, underperformance occurs in the banking sector where small local banks are preserved despite their weak performance. Furthermore, bank regulation, which occurs at the EU level, has consistently failed to deal with problems in the larger banks (Larson, 2019).

We were not able to determine which industries absorbed the influx of immigrant labour, but construction and retail trade seem likely destinations. German productivity in the trade sector is strong partly because of leading companies that operate throughout Europe and globally (Edeka, Schwartz Group, Aldi, Metro). The industry is heavily regulated which has mixed effects on labour productivity. Restrictive opening hours concentrate shopping to a shorter time period and raise measured productivity at the expense of customer convenience.[22]

In general, German manufacturing industries compare favorably to their US and Japanese counterparts in both productivity levels and employment growth. The main exception is electrical and optical equipment. German manufacturing has developed high-tech products but does not have the same level of production of computer and related products.[23]

Chart 1 showed that Germany caught up to the US level of overall productivity some years ago. It fell behind somewhat during the 1990s when the US economy was spurred by the IT sector. Although Germany has innovative tech companies, there is no equivalent of Silicon Valley in Germany. Also, regulation in services is greater in Germany. On the other hand, the US economy has no equivalent of the German worker training programs. Despite differences in the industry pattern, slow productivity growth in Germany, as in the United States, surely derives from a broad slowing in productivity-enhancing innovation, as Gordon and Sayed (2019) have suggested.

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22 Online retailing is growing in Germany but was not large over the time period shown in this study.

23 Transportation equipment has a lower level of productivity in Germany. Their auto industry is very strong but they do not have strength in aerospace for historical reasons.

Reasons for Japanese Productivity Performance

The literature also advances differing hypotheses about the reasons for productivity weakness in Japan and why Japan's productivity level stalled out well below that of Germany and the United States. One compelling reason is the performance of small businesses. They make up a large part of the economy, more than two-thirds of employment and around a half of output, and their productivity is lower relative to large companies than is the case in other advanced economies (OECD, 2019b). Competition does not drive out the low productivity companies because of the system of loan guaranties and other regulatory protections. The OECD also argues that there is a problem in corporate governance in larger firms. Japanese firms have low returns on equity and corporate boards are made up of insiders.

Jorgenson and Nomura (2005) and Jorgenson and Motohashi (2005) suggest a strong link between productivity in Japan and investment in IT. They find an increase in IT investment in Japan after 1995 and a corresponding increase in productivity growth in 1995-2000. Arora, Drev, and Branstetter (2010) also link technology to Japanese economic performance but argue that Japan fell behind the United States in software innovation so that Japanese companies were not able to keep up with Silicon Valley over the period 1983-99. A related argument is that Japan has spent heavily on R&D, but the dollars have not generated good economic results (Bahar and Strauss, 2020).

A report for the think-tank RIETI, by Fukao (2010) notes that Japan's traditional productivity strength has been in manufacturing, but this is a declining part of the economy. Fukao further argues that Japanese companies have had difficulty taking advantage of IT investment. Morikawa (2019), also from RIETI, argues that service sector productivity in Japan is understated because of limited adjustment for the improvement in quality of service sector output.

Starting in the early 1990s, the McKinsey Global Institute conducted a series of cross-country comparative productivity studies. A main result for Japan was that the most productive Japanese manufacturing industries were ahead of the United States, notably in automobiles, machine tools and steel. Despite these successful industries, average labour productivity in Japan was found to be well below that in the United States with both service industries and protected domestic manufacturing industries at a productivity disadvantage.[24] The explanation for this pattern was that Japan's leading manufacturing industries were competing against the most productive global companies while the rest of the economy was protected against imports and was often highly regulated so that domestic competition was limited, allowing unproductive (often small) firms to survive. This view is consistent with sev-

24 The studies of productivity can all be found on the McKinsey Global Institute website at https://www.mckinsey.com/mgi/overview. The early studies were described in Baily (1993) and Baily and Gersbach (1995).

eral of the arguments given in the literature described above[25] and explains the overall productivity gap in terms of Japan as a dual economy, with part of the economy highly productive and part protected.

Jorgenson, Nomura and Samuels (2018) find that the highly productive industries in Japan pushed overall manufacturing productivity above the US level in the 1990s before converging back to the US level by 2017. Low productivity outside manufacturing, in their analysis, explains all of the current TFP gap to the United States.

How do the industry findings reported in the previous sections fit in with the hypotheses advanced in the literature? We will use the JNS results. Agriculture and wholesale and retail trade are industries where there are many small firms in Japan protected from competition, and their productivity is well below the US level in 1990, with no catchup occurring. Air, water, and rail transportation have productivity levels below the United States and there is either no catchup or, in the case of air transportation, a long way to go to catch up. Finance and insurance in Japan were also not catching up.

The mining industry in Japan is very small and so the comparison to the US industry may not be meaningful. The US computer and electronics industry shows up having labour productivity below Japan in 1990 but where productivity growth is faster and so convergence has taken place.

These industry results are broadly consistent with the literature suggesting that Japan's productivity gap to the United States is concentrated in services. However, the fact that many Japanese manufacturing industries show negative TFP growth from 1990 in the JNS analysis indicates that not all of the productivity problems are in services.[26] The labour productivity results by industry also confirm the view discussed in the literature, that weak capital investment has contributed to slow Japanese growth in recent years.

Conclusion

The German economy caught up to the US level of productivity in the 1990s and has since remained close behind. Their economy lacks the innovative IT sector of the United States but has other advantages, including strong worker training. German GDP per capita is well below the US level, but that is because German workers have many fewer annual hours of work, and more leisure.

The Japanese economy grew very strongly for many years and its leading industries set new productivity frontiers. In the 1990s that relative progress stalled out and GDP per hour worked fell further behind the levels achieved in both Germany and the United States. Increasing the level of competitive intensity and driving out low productivity small and large firms would

25 The OECD study argues that good corporate governance can improve productivity, but the McKinsey studies argue that product market competition is what is needed. Given the need for tangible and intangible investment, the OECD's concern about low profitability among large firms is well-taken.

26 A 2015 study by McKinsey argues that Japanese manufacturing has fallen behind the US in high-tech production. See Desvaux et al (2015).

help complete Japan's convergence to the productivity frontier. The Japanese manufacturing sector still has strong productivity performance, setting the frontier level of productivity in some industries, but its relative performance has declined. Negative TFP growth in several manufacturing industries is concerning and suggests deeper case study analyses are needed. The literature suggests Japan may have had difficulty with software development and the application of IT.

Recent productivity growth in the United States has been very slow indeed. There are promising technologies on the horizon but so far the gains are not being realized. The results in this article point to problem industries such as construction and utilities where productivity growth is very low or negative. While it is likely that productivity measurement needs to be improved, there are also underlying problems associated with regulation and a lack of effective competition.

Benchmarking industry growth rates and productivity levels across countries is an important way to determine where countries are falling behind and where productivity gains might be achieved. There are substantial differences in results depending on which set of PPPs are used, providing a cautionary note to these results.

The world is caught up in the Covid-19 crisis as this is written. Possibly this will accelerate trends that will enhance future productivity (in retail for example) but, more likely, a slow recovery will weaken investment and trend labour productivity for a time.

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Appendix: Lessons from Productivity Comparisons of Germany, Japan, and the United States

Table A1: Total Factor Productivity Growth by Industry, US, Japan, and Germany

Average annual rate of change	**United States**				**Japan**				**Germany**			
	1991-1995	**1995-2004**	**2004-2016**	**1991-2016**	**1991-1995**	**1995-2004**	**2004-2016**	**1991-2016**	**1991-1995**	**1995-2004**	**2004-2016**	**1991-2016**
Agriculture, forestry and fishing	0.6	5.1	1.6	2.7	-	0.5	1.6	1.1*	-8.9	5.2	-2.4	-0.7
Mining and quarrying	6.2	-0.4	2.6	2.1	-8.8	3.0	-7.6	-4.0	4.7	-0.8	1.4	1.1
Manufacturing	3.1	4.4	0.7	2.4	0.1	2.0	1.8	1.6	1.4	2.5	1.9	2.0
Utilities	0.7	-0.8	-1.2	-0.8	-1.6	0.8	-3.3	-1.6	-1.5	1.7	1.2	1.0
Construction	0.1	-2.0	-1.7	-1.5	-	-1.2	0.9	0.0*	-1.8	0.2	0.3	-0.1
Wholesale and retail trade	3.1	4.0	0.6	2.2	4.2	1.7	0.0	1.3	-0.7	2.4	1.4	1.4
Transportation and storage	1.9	1.3	-0.2	0.7	0.6	-0.5	-0.8	-0.5	2.3	2.2	0.2	1.3
Information and communication	1.3	2.7	2.9	2.5	5.0	4.3	0.3	2.5	3.8	5.5	3.6	4.3
Financial and insurance activities	0.4	2.5	0.8	1.4	-1.3	-2.2	0.3	-0.9	-0.1	-2.5	1.1	-0.4
Real estate	1.3	-0.2	1.3	0.8	-	0.2	1.6	1.0*	3.3	1.1	0.3	1.1
Professional, scientific and technical activities; administrative and support service activities	-1.0	0.1	0.3	0.0	1.1	2.7	1.4	1.8	0.9	-2.6	-1.1	-1.3
Community, social and personal services	-0.6	-0.3	0.0	-0.2	-1.4	-0.5	-0.3	-0.6	1.6	0.4	0.4	0.6
Non-agriculture Business Sector excluding Real estate	**2.0**	**2.6**	**0.5**	**1.5**	**0.2**	**1.2**	**0.7**	**0.8**	**0.2**	**1.3**	**1.1**	**1.0**

Source: Calculations based on OECD Structural Analysis statistics (STAN).
Note: *1995-2016 for starred industries in Japan.

Table A2: Manufacturing Industries Total Factor Productivity Growth by Timeframe

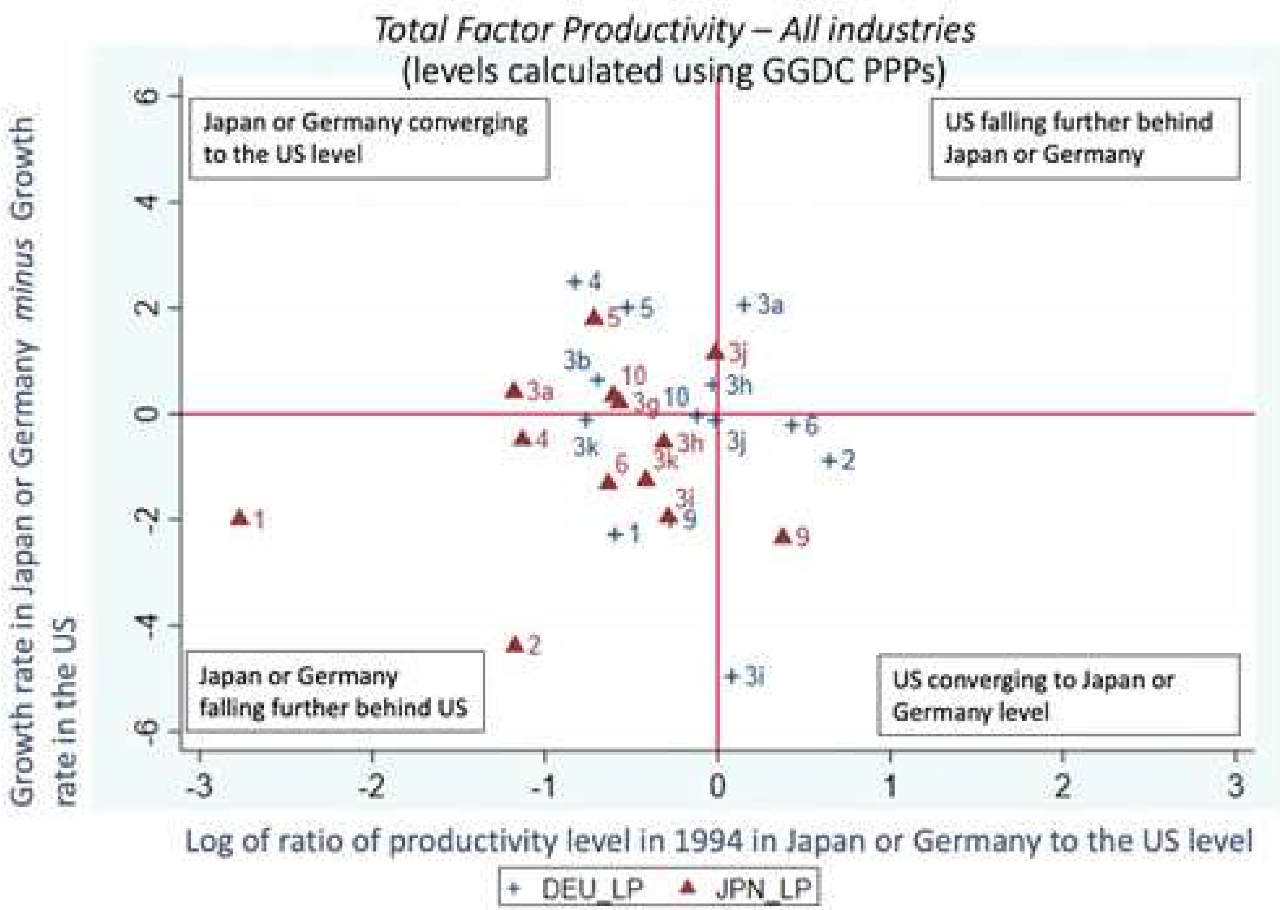
Average annual rate of change	**United States**				**Japan**			**Germany**			
	1991-1995	**1995-2004**	**2004-2016**	**1991-2016**	**1995-2004**	**2004-2016**	**1995-2016**	**1991-1995**	**1995-2004**	**2004-2015**	**1991-2015**
Food, beverages and tobacco	4.6	-0.8	-0.1	0.4	-0.1	0.0	0.0	-0.9	-0.5	1.7	0.4
Textiles, wearing apparel, leather and related	3.5	4.2	1.2	2.6	-0.5	0.3	-0.1	5.8	3.4	0.9	2.6
Wood and paper, and printing†	-3.1	2.2	1.3	0.9	0.6	0.1	0.3	2.3	2.7	2.3	2.5
Coke and refined petroleum	5.1	13.2	-1.0	5.1	-0.3	-0.9	-0.6	-	-	-	-
Chemical and pharmaceuticals	3.0	3.9	0.9	2.3	2.5	1.5	1.9	8.1	4.7	0.9	3.5
Rubber and plastics	1.4	4.7	0.3	2.0	-	-	-	4.5	2.3	1.3	2.2
Other non-metallic minerals	3.1	2.0	-0.1	1.2	2.7	-0.3	1.0				
Basic metals and fabricated metal products	2.3	2.7	0.4	1.6	0.9	0.3	0.5	3.2	2.4	0.7	1.8
Electrical, electronic and optical equipment	14.6	15.5	6.9	11.2	10.4	7.3	8.7	3.7	5.6	3.7	4.4
Machinery and equipment n.e.c.	0.1	2.0	0.5	1.0	1.8	3.1	2.6	3.9	1.6	-0.7	0.9
Transport equipment	0.2	4.1	2.3	2.6	2.1	0.5	1.1	1.3	1.4	4.5	2.8
Furniture; other manufacturing	0.7	3.7	1.3	2.1	-	-	-	2.0	3.4	0.7	1.9
Manufacturing	**3.6**	**6.1**	**1.9**	**3.7**	**3.3**	**2.4**	**2.8**	**3.2**	**2.9**	**1.9**	**2.5**

Source: Calculations based on OECD Structural Analysis statistics (STAN).
Note: †Paper and paper products for Japan.

Table A3: JNS Industry Labels for Chart 3

Industry	Industry Name
1	Agriculture, Forestry, Fishery
2	Mining
3	Construction
4	Foods
5	Textile
6	Apparel and Leather Products
7	Woods and Related Products
8	Furniture and Fixture
9	Paper and Pulp
10	Printing and Publishing
11	Chemical Products
13	Stone, Clay, Glass
14	Primary Metal
15	Metal Products
16	Machinery
17	Computer and Electronic Products
18	Other Electric Machinery
19	Motor Vehicles
20	Other Transportation Equipment
21	Miscellaneous Manufacturing
22	Rail Transportation
23	Water Transportation
24	Air Transportation
25	Road Transportation
26	Other Trans and Storage
27	Communications
29	Wholesale and Retail
30	Finance and Insurance

Chart 1: Industry Productivity Growth Differentials (1995-2016) against Productivity Levels (1994) Relative to the United States. Japan and Germany, all industries, total factor productivity.



Source: Calculations based on GGDC PPPs and OECD STAN data.
Note: Major industry labels in Table 3. Manufacturing industry labels (subpart 3) in Table 4.

Does Disappointing European Productivity Growth Reflect a Slowing Trend? Weighing the Evidence and Assessing the Future

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Abstract

In the years since the Great Recession, many observers have highlighted the slow pace of labor and total factor productivity (TFP) growth in advanced economies. This paper focuses on the European experience, where we highlight that trend TFP growth was already low in the runup to the Global Financial Crisis (GFC). This suggests that it is important to consider factors other than just the deep crisis itself or policy changes since the crisis. After the mid-1990s, European economies stopped converging, or even began diverging, from the U.S. level of TFP. That said, in contrast to the United States, there is some macroeconomic evidence for some northern European countries that the GFC had a further adverse impact on TFP growth. Still, the challenges for economic policy look surprisingly similar to the ones discussed prior to the Great Recession, even if the policy implications seem less clear.

Across advanced economies, the recovery from the Great Recession was disappointingly slow. Initially, observers pointed primarily to temporary disruptions and dislocations from the crisis itself. But as the recovery continued, GDP growth remained subdued. Well before the massive 2020 health and economic shock from COVID-

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19, there was an increasing recognition that trend output growth rates were slow. For Europe as well as the United States, the "surprise," relative to expectations from the pre-2007 period, has been in labour productivity. After all, the demographics of an aging population were largely foreseen.[2]

We survey the European productivity experience from a macroeconomic perspective. We argue that the slow trend is not simply the "long shadow" (Fatás, 2000) cast by the Global Financial Crisis (GFC) — as disruptive as that event was. Indeed, both labour and total factor productivity (TFP) were slowing prior to the GFC. Statistical break tests on TFP growth do provide some tentative evidence of a post-2007 break for at least some northern European economies. But even if the GFC did lead to some further decline in trend TFP growth, that growth rate was already relatively modest.

Chart 1 illustrates the slowing TFP trend. The data are a weighted average of TFP growth for the 15 pre-2004 European Union countries from the Penn World Tables (PWT, Feenstra *et al.*, 2015). TFP growth has been slowing since the 1960s. Of course, much of that slowdown was benign, reflecting the end of the convergence "boost" that Europe received after World War II. But, as we discuss, the further slowdown since the 1990s reflects a different pattern. Some countries have been falling rapidly away from the frontier (notably Spain and Italy). In Northern Europe, countries stopped converging short of U.S. levels, or have even (depending on the dataset) drifted gradually down relative to the United States.[3]

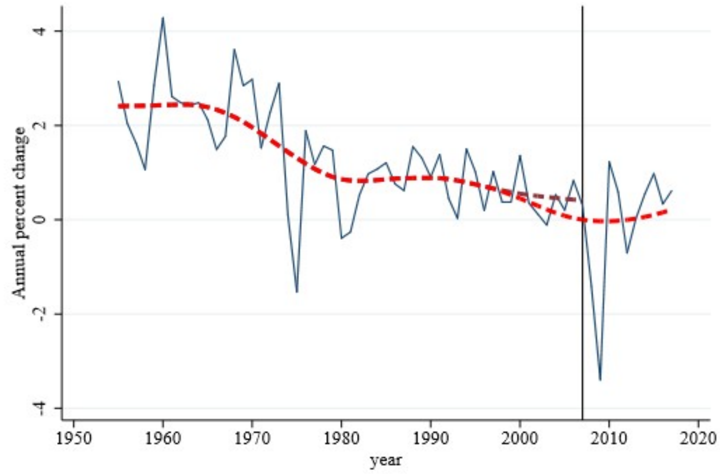
Chart 1 shows two estimated trend lines from a biweight filter. This filter is close to a 12-year centered moving average that becomes increasingly one-sided at the end points. The red-dashed line uses data through 2017. The full-sample TFP trend falls to near zero growth by 2005 and remains there. Of course, the pre-2007 values of the full-sample filter are pulled down by the sharp negative growth that subsequently occurred in 2008 and 2009. For this reason, the maroon-dashed line is estimated using data through 2007 only. That quasi-real-time trend line lies above the estimated full-sample trend after the late 1990s. But it nevertheless stood at only 0.4 per cent per year on the eve of the 2007-9 Great Recession, down from 0.9 per cent in the early 1990s.

Indeed, before the recession, a large literature addressed the puzzle that Europe had seen a mid-1990s productivity slowdown even as the United States had seen

2 For major European economies, which is our focus, labour force growth from 2010-2019 has actually exceeded the (slow) projections by the European Commission (Carone *et al.*, 2006), reflecting increases in labour force participation (Gros, 2019). But labour productivity growth has fallen short of 2006 projections.

3 Cette *et al.* (2016) found, using data from Bergeaud *et al.* (2016), that total economy TFP levels in major European countries were similar to U.S. levels by the mid-1990s, but subsequently lost ground relative to U.S. levels. PWT, Conference Board (2019), and OECD data also show that TFP growth in most European countries fell short of the U.S. pace from 1995-2007. In contrast, in market-sector EU KLEMS (2017) data that we use for some of our analysis, TFP growth in Northern Europe was very close to the U.S. pace from 1995-2007. In any case, we find that the level of market-sector TFP for major European economies was uniformly below the U.S. level after the early 1990s. Even in EU KLEMS, northern European countries lost ground relative to the United States over the full 1995-2015 period.

Chart 1: European Total Factor Productivity Growth, 1995-2017



Source: Source is PWT 9.1 (Feenstra, Inklaar, and Timmer, 2015).
Note: The solid line is European TFP growth, defined as a Törnquist index of TFP growth for 15 countries that were members of the European Union before 2004. Country TFP is variable RTPNA, and weights are nominal PPP-adjusted GDP, variable CGDPO. Countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. The red dashed line is biweight trend with bandwidth of 12 years. The maroon dashed line that diverges from the red line after the late 1990s, and ends in 2007, is the estimated trend using data through 2007 only.

a pickup. Timmer *et al.* (2010, 2011) reviewed the pre-GFC debate. They concluded that European economies had not fully adapted to a knowledge-based economy, in terms of flexibility, skills, management, and such. Cette *et al.* (2016), similarly emphasize the pre-GFC origins of slowing TFP growth in Europe.

For most of the article, we focus on TFP growth, which adjusts for observable capital growth as well as the educational qualifications of the workforce. The reason is that the source of weak labour productivity growth has been the anemic pace of TFP growth. We find that weak capital formation — investment in plant, equipment, software, and the like — has played at most a small direct role. Capital-output ratios, in particular, do not look low relative to pre-recession trends.

In the United States, the leading hypothesis for the disappointing output recovery after the Great Recession is that the deep recession was superimposed on a sharply slowing output growth trend. That slow trend, in turn, was largely independent of the Great Recession itself (Fernald *et al.*, 2017). The mid-1990s productivity boom ended several years prior to the Great Recession (Fernald, 2014; Fernald *et al.*, 2017). For example, quarterly TFP growth from the end of 2004 through 2007 was slower than it was from the end of 2007 through 2019. In addition, the U.S. slowdown was observed before the recession, and professional forecasters were already at least partially accounting for it (Fernald *et al.*, 2017). Information and communications technology (ICT) had provided an exceptional boost to trend TFP growth in the mid-1990s and early 2000s. The waning trend plausibly reflected a pause in (if not the end of) those exceptional gains.

Consistent with this view, Bloom *et al.* (2020) argue that "ideas are getting harder to find" (Bloom *et al.*, 2020). Closely related, Aghion *et al.* (2019) and de Ridder (2020) provide endogenous-growth models in which the initial gains from ICT eventually lead to reduced innovation throughout the economy as well as reduced dynamism. For the United States, the best guess at this point is thus that trend growth remains low (Fernald and Li, 2019).[4]

We view Europe's experience as broadly consistent with the same narrative. The unusually deep and long recession was superimposed on a slowing productivity trend. Unlike the U.S. case, though, there is some evidence that the GFC might have led to a further decline in TFP growth in some countries. But even in Europe, pre-2007 trend growth was slower than in the late 1990s, let alone the late 1980s[5].

Conceptually, Europe's TFP trend reflects not only the U.S. trend, but also "distance to the frontier." Many countries in Europe have either remained short of the frontier — as we find here — or else fell further behind the frontier. From a conditional convergence perspective, it remains unclear where to pin a new steady state for many European economies relative to the United States — and indeed, one challenge is to characterize the disparate pattern *across* European economies. While Northern European countries have modestly lost ground relative to the United States, Southern European countries have lost considerable ground since the 1990s. There is little evidence that countries in Europe are closing the gap with the United States.[6]

The primary alternative to our 'slowing underlying trend' view is the hypothesis that the productivity slowdown was, in fact, primarily a result of the GFC. There is no question that the crisis was a traumatic and disruptive event across advanced economies. Fatás and Summers (2018) find a permanent effect of the crisis on potential output in many or most countries. There are many channels through which such hysteresis could work, with TFP being one of them.[7] A superficial look at the data does suggest reasons for focusing on TFP effects: major European economies have had very weak (if not negative) average TFP growth

4 There are complementary stories that emphasize regulation. For example, Fernández-Villaverde and Ohanian (2018) argue that regulation and a lack of competition have led to weak growth in Europe as well as the United States. That said, Fernald *et al.* (2017) find no quantitative evidence that regulatory changes have a first-order impact on U.S. TFP growth. Philippon (2019) argues that Europe is now more competitive than the United States.

5 Fernald (2018) provides an earlier view on this topic, discussing evidence for the United States and other advanced economies. The conclusion in that paper also emphasized the pre-GFC productivity growth slowdown. In contrast to the current paper, it largely played down the role of the GFC itself.

6 See also Gordon and Sayed (2019). They argue that Europe has been catching up to the United States in stages. They note that the "early to late" slowdown in labour productivity growth was similar in western Europe and the United States — but the "early" U.S. period was pre-1973, whereas the early European period was 1972-95.

7 Oulton and Sebastiá-Barriel (2017) survey the literature and provide estimates of several of the channels. Conceptually, hysteresis in output growth reflects either hysteresis in labour input, or hysteresis in labour productivity. On the labour side, workers who spend an extended period unemployed may well lose labour market skills; because they are harder to employ, the natural rate of unemployment rises. Workers may also lose attachment to the labour market and move out of the labour force. In term of labour productivity, we discuss capital deepening and TFP below.

since 2007.[8] Drawing direct conclusions based on these weak growth rates is hard, however, because recessions often lead to a decline in *measured* TFP growth. Factor utilization (labour effort and capital's workweek) tends to fall in recessions but is not directly observed in the standard input measures.

But a deep recession could have persistent, adverse effects on TFP growth (e.g. Adler et al, 2017). Possible channels include reduced incentives to innovate (e.g. Bianchi *et al.*, 2018; Anzoategui *et al.*, 2019; Garga and Singh, 2020); increased misallocation of resources in some economies (e.g. Gopinath *et al.* 2017); or increased credit frictions that further reduce investment in intangibles such as R&D, organization capital, and training (e.g. Duval *et al.*, 2017).

But even if these factors are important, the evidence from Chart 1 and later sections of this article suggest that any effects of the GFC were on top of an already-slowing TFP trend. This is particularly true relative to the United States, where the pre-recession timing of the TFP slowdown is well established. At a minimum, these facts suggest limits to some popular stories in which the Great Recession caused the slow pace of productivity growth.

This article is structured as follows. Section 1 documents some key facts that inform the debate. We focus especially on TFP growth because, as we discuss, we do not see weak capital formation as an important independent channel for explaining weak growth in labour productivity. Section 2 examines break tests on TFP growth. We find some evidence for some countries pointing to a structural break after 2007, but this partly depends on the dataset and level of aggregation. Section 3 looks at cyclical aspects of TFP dynamics. It is challenging, in the European context, to control for cyclical effects directly because of the heterogeneity in institutions and the lack of suitable proxies for cyclical mismeasurement. Cyclical mismeasurement issues might still affect the EU KLEMS numbers we use through 2015, but they had plausibly run their course by the end of the PWT sample in 2017. Section 4 draws upon the literature and discusses evidence on various additional issues that could affect how we interpret the TFP growth slowdown, including vintage capital models, demographics, market power, and intangible capital. Section 5 discusses how to interpret the facts and draws some lessons for the future.

Key Facts and Conceptual Framework

This section starts by motivating our focus on TFP growth. Weak TFP growth is the key to understanding weak labour

8 In the Conference Board's (2019) Total Economy Database, aggregate TFP growth in virtually all European economies was zero or negative in the 2007-2018 period (exceptions were Germany, Iceland, Ireland, and Malta). In the EU KLEMS 2017 market economy database from 2007-2015, TFP growth in all countries other than Belgium was negative (Chart 4). In the PWT from 2007-2017, for the same set of countries, only Germany had positive TFP growth. In OECD data for 2007–2018, most European countries show TFP growth rates close to zero (ranging from -0.1 per cent per year to 0.1 per cent per year), with the exceptions of Denmark (0.5 per cent), Germany (+0.5 per cent), Ireland (1.0 per cent), Italy (–0.3 per cent), Luxembourg (–0.8 per cent) and Greece (–1.9 per cent).

Table 1: Growth Accounting Data for Europe

	(1) 1985-95	(2) 1995-07	(3) 2007-17	(4) 1995-00	(5) 2000-07	(6) 2007-11	(7) 2011-17
(1) Labour productivity growth	2.48	1.50	0.68	1.74	1.33	0.34	0.91
Accounting decomp. 1 (p.p. contributions):							
(2) Capital/hour	1.09	0.72	0.55	0.73	0.72	0.80	0.39
(3) Labour composition	0.44	0.32	0.25	0.35	0.29	0.28	0.22
(4) TFP growth	0.95	0.47	-0.12	0.67	0.32	-0.74	0.30
Accounting decomp. 2 (p.p. contributions):							
(5) Capital/output	0.21	0.19	0.45	0.04	0.29	1.11	0.01
(6) Labour composition	0.72	0.53	0.42	0.58	0.50	0.48	0.38
(7) TFP growth	1.55	0.78	-0.19	1.12	0.54	-1.25	0.52

EU KLEMS Market Sector (combination of 2012 and 2017 version)

	1985-95	1995-07	2007-15	1995-00	2000-07	2007-11	2011-15
(1) Labour productivity growth	2.41	1.66	0.42	1.84	1.53	0.15	0.69
Accounting decomp. 1 (p.p. contributions):							
(2) Capital/hour	1.11	0.88	0.45	1.05	0.76	0.63	0.26
(3) Labour composition	0.37	0.20	0.30	0.19	0.20	0.33	0.27
(4) TFP growth	0.93	0.65	-0.30	0.73	0.60	-0.78	0.19
Accounting decomp. 2 (p.p. contributions):							
(5) Capital/output	0.56	0.51	0.48	0.69	0.39	0.88	0.08
(6) Labour composition	0.53	0.29	0.43	0.28	0.29	0.48	0.38
(7) TFP growth	1.33	0.96	-0.45	1.06	0.89	-1.16	0.27

Note: All data are Törnquist aggregates across individual countries. See the text for the expressions shown in lines 2 through 7. Penn World Tables aggregates the 15 countries that were members of the European Union before 2004; see notes to Chart 1 for the list. Because of data availability, EU KLEMS includes eight countries with complete growth-accounting data back to 1985. EU KLEMS ends in 2015, whereas PWT ends in 2017. See the online Data Appendix for further details. The text explains the two accounting decompositions.

productivity growth across Europe. Specifically, we find that a shortfall of capital formation was not an important independent contributor to weak labour productivity growth. We then highlight some of the differences in TFP levels and growth rates across countries and discuss how the trends fit into a framework of conditional convergence.

The takeaways are that TFP is the right place to look for understanding weak labour productivity growth in Europe; that the pace was slowing and heterogeneity across countries was rising even before the Great Recession; and that stories that focus on particular sectors in particular countries (e.g. construction in Spain) do not explain the broad-based slow pace of TFP growth.

Accounting for European Labour Productivity: TFP and Capital Deepening

Table 1 shows two complementary growth-accounting decompositions since 1985 for the Penn World Tables (PWT) and EU KLEMS datasets. In both cases, the accounting covers a European aggregate. PWT covers the entire economy, whereas EU KLEMS (which merges the 2012 and 2017 vintages) shows the market sector.[9] EU KLEMS covers Austria, Finland, France, Germany, Italy, the Netherlands, Spain, the United Kingdom for a sufficiently long period. PWT has more data availability, covering all 15 countries that were members of the European Union prior to 2004 — which adds six countries: Belgium, Denmark, Greece, Ireland, Portugal, and Sweden. Within each dataset, output, capital, hours, TFP, and labour composition are appropriate PPP-adjusted Törnquist aggregates.

Line 1 of each panel in Table 1 shows that, broadly speaking, labour productivity growth has fallen steadily over time. For example, in PWT, labour productivity grew 2.5 per cent per year in the 1985–1995 period, 1.5 per cent in the 1995–2007 period, and only 0.7 per cent in the 2007–17 period.

Looking at shorter subperiods in columns 4 to 7, the exception to the steady decline is that labour productivity growth was particularly weak in the 2007–11 period and rebounded somewhat in the 2011–17 period. That period runs from one euro-area business-cycle peak to another. But the rebound from the deep 2008–9 recession was incomplete by 2011. So cyclical influences on productivity were still pronounced over this subperiod, a topic we return to in Section 3.

Table 1 then shows two complementary growth-accounting decompositions of labour productivity. Both decompositions start with the basic growth-accounting identity that implicitly defines TFP growth, $\Delta \ln TFP_t$:

$$\Delta \ln Y_t = \alpha_t \Delta \ln K_t + (1 - \alpha_t)(\Delta \ln H_t + \Delta \ln LC_t) + \Delta \ln TFP_t \quad (1)$$

In this equation, $\Delta \ln Y_t$ is output growth, $\Delta \ln K_t$ is capital growth, $\Delta \ln H_t$ is hours growth, and $\Delta \ln LC_t$ is labour composition growth. α_t is the nominal share of payments to capital in revenue (which, in practice, we take to be the average in years $t-1$ and t), and $(1-\alpha_t)$ is labour's share. We assume the factor shares sum to one.[10]

Rearranging equation (1) yields our first decomposition, shown in lines 2 to 4 of Table 1:

$$\Delta \ln Y_t - \Delta \ln H_t = \alpha_t(\Delta \ln K_t - \Delta \ln H_t) + (1-\alpha_t)\Delta \ln LC_t + \Delta \ln TFP_t \quad (2)$$

9 The main takeaways are robust across these and other datasets shown in the online Data Appendix available at http://www.csls.ca/ipm/38/fernald-appendix.pdf. The additional datasets are the Conference Board's Total Economy Database (TED) and the OECD. The Data Appendix also shows data from the 2019 vintage of EU KLEMS (Stehrer, 2019). The 2019 vintage starts in 1995 but appears inconsistent with the 2012 vintage, so it is not appropriate to merge them. More concerningly, the capital data in the 'statistical database' of the 2019 vintage (which, like other sources, includes only national accounting intangibles), is quite different from other sources — growing more slowly throughout the period since 1995. Pending further analysis of the sources of the differences, we have chosen to include the 2019 vintage in the Data Appendix but not the main text. For the 2012 and 2017 versions of the EU KLEMS database, see www.euklems.net. For the 2019 version, see www.euklems.eu.

10 Under standard conditions of constant returns to scale, perfect competition, and perfect factor mobility (Solow, 1957), TFP growth defined by this equation represents the outward shift in society's production possibilities frontier from technological change. A large literature has explored the interpretation of TFP growth when these conditions fail (e.g. Basu and Fernald, 2002; Oulton, 2016). For our purposes, we simply take equation (1) as implicitly defining aggregate TFP growth as the part of aggregate output growth that is not explained by revenue-share-weighted growth in capital and labour inputs.

The first term captures the contribution of changes in the ratio of capital to hours. Intuitively, workers have more "tools" to work with, they will be more productive per hour worked. The second term is the direct contribution of changes in labour composition. This term captures changes in the educational qualifications of the labour force; for example, workers with more education or experience are typically more productive. The third term is standard TFP growth.

With this first decomposition, the vast majority of the slowdown in labour productivity after 2007 occurs through slower TFP growth (line 4). Looking at the PWT data, TFP growth falls from 0.95 per cent per year from 1985–95 (column 1) to 0.47 per cent from 1995–2007, to –0.12 per cent per year from 2007–2017 (column 3).

The sharp slowdown in TFP growth is also apparent in the EU KLEMS market sector — where TFP growth slows between 1995-2007 and 2007-2015 by almost a percentage point (from 0.65 per cent to -0.30 per cent). In EU KLEMS, capital deepening slows somewhat more than in PWT after 2007 (where the contribution in line 2 falls about 0.2 percentage points). But in both cases, after 2007, slower growth in capital deepening (line 2) is only a modest to moderate contributor to the labour productivity slowdown. A slowdown in labour composition growth (line 3) contributes even less to the slowdown. Indeed, in EU KLEMS, labour composition grows *more* quickly after 2007.

This decomposition arguably overstates the contribution of capital deepening to the labour-productivity slowdown because of the endogeneity of capital. For example, in the Solow (1956) growth model, all growth in output per hour comes from TFP growth. But equation (2) — which closely follows Solow (1957) — would attribute some of that growth to increases in capital per hour. Perhaps more relevant for interpreting Table 1, in neoclassical growth models, a slowdown in trend TFP growth naturally leads to slower growth in capital per hour.[11]

Fernald *et al.* (2017) suggest using a complementary decomposition of labour productivity in terms of the capital-output ratio. This approach (partially) adjusts for the endogeneity of capital. In particular, a rearrangement of the above equations yields the following:

$$\Delta \ln Y_t - \Delta \ln H_t = \frac{\alpha_t}{1-\alpha_t}(\Delta \ln K_t - \Delta \ln Y_t) + \Delta \ln LC_t + \frac{\Delta l \ln TFP_t}{1-\alpha_t} \quad (3)$$

This expression is useful because, even though capital formation is endogenous, in many models the capital-output ratio is stationary in steady state (through possibly with a trend, if there are trends in the

11 In the Solow (1956) model, for example, steady-state capital per hour grows at the rate of labour-augmenting technical progress, which in turn equals TFP growth divided by labour's share. So slower growth in TFP leads to slower growth in capital per worker; this is true in the transition as well as in steady state. Oulton (2019) suggests a model in which the post-2007 world saw output growth constrained by demand for exports. In this "bad regime," the neoclassical relationships do not hold (even though the production structure of the model is neoclassical). But in that bad regime, the capital-output ratio would fall, unlike what we find in the data.

relative price of investment goods). Slower growth in technology and labour naturally lead to a lower path for both capital and output — but, in neoclassical models, will not show up as a decline in the capital-output ratio. Thus, the capital-output ratio can help diagnose whether there are special influences that reduced capital relative to output. Such influences could reflect, say, unusual credit constraints or heightened uncertainty that reduce investment (and, over time, capital) more than one would expect just from a weaker/slower-growing economy.

In both the PWT and EU KLEMS, the contribution of the capital-output ratio (row 5) is not notably lower in the post-2007 period (column 3) than in the preceding period. This is particularly the case in the PWT, where the contribution rose more than 0.25 percentage points per year since 2007 relative to the 1995–2007 period. In other words, faster growth in the capital-output ratio added *positively* to labour productivity growth, even as labour productivity growth slowed.

What this implies is that the reduced contribution of TFP (row 7) *more than* explains the slowdown in labour productivity growth. In both the PWT and the EU Klems data sets note that the TFP contribution in row 7 is $\Delta \ln TFP_t \; / (1-\alpha_t)$, which expresses technology growth in labour-augmented form. By dividing by labour's share of income, it exceeds the direct effect of TFP growth from row 4. The economic effect this captures, in neoclassical models, is the induced capital growth that results from TFP growth.

Chart 2 makes our argument visually. Panel A of Chart 2 plots the capital-output ratio in the PWT data for the EU-15, with selected years (1995, 2007, 2010, and 2017) shown for the five largest European economies. For visual clarity, the plot is in levels (the integral of the term in equation 1), normalized to 2007=1. The European capital-output ratio has an upward trend, consistent with positive investment-specific technical change. But since 2007, the European capital-output ratio lies above any reasonable extrapolation of the 1995-2007 trend. That is, there is no broad-based shortfall in capital relative to output.

The labeled points show that major economies other than Germany have the same general pattern. In France, the United Kingdom, Italy, and Spain, the 2017 capital-output ratio lies above its pre-recession trend (which, for all countries other than the U.K., was upward). Germany had an upward trend from 1995 to 2007, but (after a recession-induced increase to 2010) has fallen short of its 2007 level, or its pre-recession trend.

That capital deepening explains little or none of the European productivity slowdown may seem surprising. It is "conventional wisdom" that investment in many countries fell sharply after 2007 and has been slow to recover. Panel B in Chart 2 shows the nominal ratio of gross investment to output, aggregated over the 15 original EU countries. The ratio has fallen steadily since the 1980s. More relevantly, it fell about three percentage points further from 2007 to 2013 — from 22 per cent to 19 per cent — following the GFC.

But, despite the lower rate of *gross* investment, *net* investment (gross investment less depreciation) remained positive. So, capital — both the stock and (more rele-

Chart 2: Trends in Capital-Output Ratios and Investment Shares in Europe

Panel A: Capital-Output Ratio

Source: Source is PWT 9.1 (Feenstra, Inklaar, and Timmer, 2015), variable RK^{NA} and $RDGP^{NA}$.
Note: Chart shows the capital-output ratio in the EU-15 for 1990-2017 and for France (FRA), Germany (DEU), Italy (ITA), Spain (ESP) and United Kingdom (GBR) the values in 1990, 2000 and 2017. The capital-output indez is normalised to 2007=1.

Panel B: Investment Share

Source: Source is PWT 9.1 (Feenstra, Inklaar, and Timmer, 2015).
Note: Nominal gross fixed capital formation relative to nominal GDP for the 15 original EU member countries.

vantly for the growth-accounting) the service flow — continued to grow. As one would expect, lower gross and net investment did lead to slower growth in capital after 2007. In the EU-15, capital services growth slowed from 2.5 per cent per year from 2000–2007 to only 1.4 per cent from 2007–2017. But output growth slowed slightly more, from 2.1 per cent to only 0.7 percent. Thus, despite the decline in the investment rate, the capital-output ratio rose slightly faster in the 2007–2017 period relative to the 2000–2007 period.

One notable feature of the data is that the capital-output ratio is strongly countercyclical (rising in recessions). In Panel A of Chart 2, this shows up in the temporary increase from 2007 to 2010. Output fell but capital did not decline (in part because we do not observe the utilization of the capital stock).[12] Returning to Table 1, it shows up as a sharp rise in the contribution of the capital-output ratio in the 2007–11 period (row 5, column 6). The contribution then barely grows in the subsequent period (from 2011 to 2015 for EU KLEMS, or 2011 to 2017 in PWT). Some observers have focused on the post-2010 period, both in Europe and the United States, to argue that subdued capital formation was behind weak labour productivity growth. In a narrow sense, it is true that capital deepening added less than earlier (and it also true with the first decomposition, which focuses on the capital-per-hour contribution in line 2).

But the chart makes clear that this is a cyclical effect. Capital deepening naturally added more, in an accounting sense, during the recession itself. But, intuitively speaking, firms came out of the recession with spare capacity (i.e., capital) relative to demand or relative to labour. Over time, they have brought capital back into line with demand and labour — which meant, for a time, having less capital deepening. Our preference is to look at the entire period from 2007 on — as shown in column (3) of Table 1, or in Chart 2 — where it is clear that a shortfall of capital deepening was not an important reason for the shortfall in labour productivity growth.

Thus, neither Table 1 nor Chart 2 suggest that a shortfall in capital formation is a major additional contributor to weak labour productivity growth as of 2017. For this reason, in what follows, we continue to focus on TFP.[13]

TFP Growth Across Countries and Industry Groups

Chart 1 showed the long downward trend in European TFP growth. The long-term slowing trend reflects several forces. One is the end of post-war economic convergence. By most accounts, convergence had run its course by the mid-1990s, if not

12 Fernald *et al.* (2017) adjust for this countercyclicality using the U.S. unemployment rate, which is approximately stationary. In Europe, the unemployment rate is less obviously stationary — the natural rate of unemployment changes over time — so it is harder to separate the cycle from the trend.

13 As noted, the cyclical dynamics of capital deepening will add additional cyclical dynamics to labour productivity, above any cyclical dynamics in TFP. Specifically, this suggests a reason not to focus narrowly on labour productivity growth after 2011, when capital-output ratios were returning to steady state from cyclically-elevated levels.

earlier (Timmer *et al.*, 2010). A second, and potentially more worrying, force for some countries is a deterioration relative to the U.S. frontier following the U.S. ICT boom of the mid-1990s. This renewed divergence was the focus of considerable literature (see, for example, Timmer *et al.*, 2010, and Cette *et al.*, 2016).

Chart 3 provides a perspective on the levels and trends. It shows TFP levels from 1985 to 2015 for the market sector in selected regions, combining data on growth rates from EU KLEMS (2012 and 2017) with TFP-levels estimates from Inklaar and Timmer (2009).[14] In these data, the U.S. economy is always at the overall frontier, as shown by the blue solid line at the top of the chart. The data are normalized so that the U.S. market-sector TFP level is 1 in 1995.[15]

In the EU KLEMS data, U.S. market-sector TFP growth from 1995 to 2005 averaged 1.2 per cent per year but slowed to under 0.2 per cent thereafter. Fernald (2014b) analyzed a range of U.S. (quarterly) productivity series. Depending on the series, he found statistically significant break dates for the productivity slowdown that ranged from 2003:Q4 to 2006:Q1. When using the unemployment rate as a cyclical control, Fernald et al (2017) find a statistically significant break in TFP growth in 2006:Q1; if growth is modeled as having smoother changes in trend, rather than discrete breaks, the slowdown was even earlier.[16] In all cases, the U.S. slowdown took place several years before the Great Recession began.

The red solid line in Chart 3 shows the (PPP) GDP-weighted average market-sector TFP level for six northern European economies, with the shaded region showing the range across these economies. In these data, the dominant feature is that all of the levels lie below the U.S. frontier after the early 1990s. In other words, with the Inklaar-Timmer (2009) estimates of TFP levels, no major European country has achieved the U.S. level of market-sector productivity.

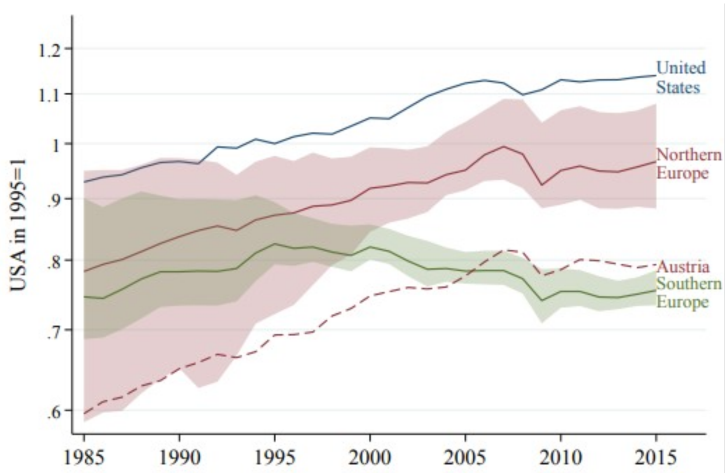
For the "typical" (weighted-average) northern European country, the solid red line shows a very modest decline relative to the U.S. level. Northern Europe lost ground from about 1995 to 2005 by about 0.5 per cent per year — driven especially by strong growth of U.S. TFP. But in 2006 and 2007, TFP in northern Europe surged, undoing the 1995–2007 relative decline. Thus, averaging over the entire 1995–2007 period, TFP growth in these data was essentially identical in the United States and north-

14 The market sector aggregates across all industries excluding real estate (industry code L); public administration and defense (O); education (P); health and social work (Q); and activities of households (T).

15 Comparing productivity levels is even more challenging than measuring growth over time, especially at the industry level, where comparative price data is much sparser. The current combination of sources is chosen, because the changes in relative levels over time are (by construction) consistent with the EU KLEMS growth data. Enforcing this consistency is not necessary when comparing productivity levels at different points over time is the main goal, as discussed in Inklaar and Diewert (2016). But relying on the Inklaar and Diewert (2016) results shows a broadly similar evolution of relative levels as in Chart 3.

16 The Fernald *et al.* (2017) analysis uses quarterly business-sector TFP data from Fernald (2014a). The TFP slowdown in that dataset is from 1.8 per cent per year from 1995:Q4-2004:Q4 to 0.4 per cent from 2004:Q4 through 2018:Q1 — somewhat sharper than in EU KLEMS.

Chart 3: Market Sector TFP Levels in Europe and the United States, 1985-2015



Source: Market-sector TFP growth from EU KLEMS 2017, combined with EU KLEMS 2012 (before 1995). PPP-adjusted TFP levels are based on Inklaar-Timmer (2009) for 1997.
Note: North: Belgium, Finland, France, Germany, Netherlands, UK. South: Italy, Spain.

ern Europe. (As footnote 2 notes, other datasets show Europe — even northern Europe — falling short of U.S. growth rates in the 1995-2007 period.)

But Northern Europe stepped down sharply during 2008-9, and that step-down did not reverse. Instead, after 2009, the pace of growth in both the United States and northern Europe was similarly low. The further bad news for northern Europe is that the level of TFP has remained stuck noticeably below U.S. levels.

Of course, the European experience has been heterogeneous, both in levels and in growth rates — even within "northern Europe." One outlier, in levels, is Austria, which looks like northern Europe in terms of growth rates but, in these data, has a much lower level of TFP. But the more noticeable outliers, in both levels and growth rates, were in southern Europe (the green shaded region).[17]

In levels, southern Europe in the early 1990s started off close to northern Europe, as shown by the overlap of the shaded regions. But TFP growth in Italy and Spain was sharply negative over this period, dragging down the level relative to the north, or relative to the United States. A sizeable body of research argues that growing misallocation, possibly associated with capital flows that came with the introduction of the euro, has dragged down productivity growth in Italy, Spain, and elsewhere. In this view, it is not that knowledge was "forgotten" in some sense but, rather, that resources were allocated increasingly to less-productive firms. Indeed, some high productivity producers might not be able to produce at all, because of barriers to entry.[18]

Even within Europe, the cross-sectional

17 Denmark is omitted from this chart, since it was not included in the EU KLEMS 2012 data and, thus, are only available from 1995 onwards.

18 See, for example, García-Santana et al (2020) and Gopinath *et al.* (2017). Restuccia and Rogerson (2017) provide a general survey of misallocation as an explanation for productivity differences across countries.

standard deviation of (log) TFP levels (derived from Chart 3) has risen since the early 2000s. Within Northern European countries, the standard deviation steadily decreased from 0.16 in 1985 to 0.05 in 2003, before increasing to 0.08 by 2015. Across all European countries in the chart, the standard deviation fell from 0.17 in 1985 to a low of 0.09 in 2001 before rising to 0.13 in 2015. While the slowdown at the frontier of growth might affect everyone, some European countries have maintained ground relative to the U.S. frontier, whereas other countries have lost ground. No major European country, according to these data, has achieved that frontier. The slow trend in Europe is thus *not* just a story of slowing frontier growth — there is still room for country-specific factors that explain why European countries have stayed inside the frontier. Note that the dispersion between European countries started to increase well before 2007.

Chart 4 provides another perspective on the cross-country heterogeneity by using EU KLEMS data to decompose market economy TFP growth into the percentage-point contributions by several industry group. The height of the bars in each panel shows average TFP growth for 11 European countries as well as the United States, ordered from slowest growth to fastest growth for each time period. Panel A shows growth from 1995 to 2007; Panel B shows growth from 2005 to 2017. Market-sector TFP growth is decomposed into five broad groupings of industries: ICT production, non-ICT manufacturing, market services, "bubble sectors" of finance and construction, and everything else (agriculture, mining, and utilities).

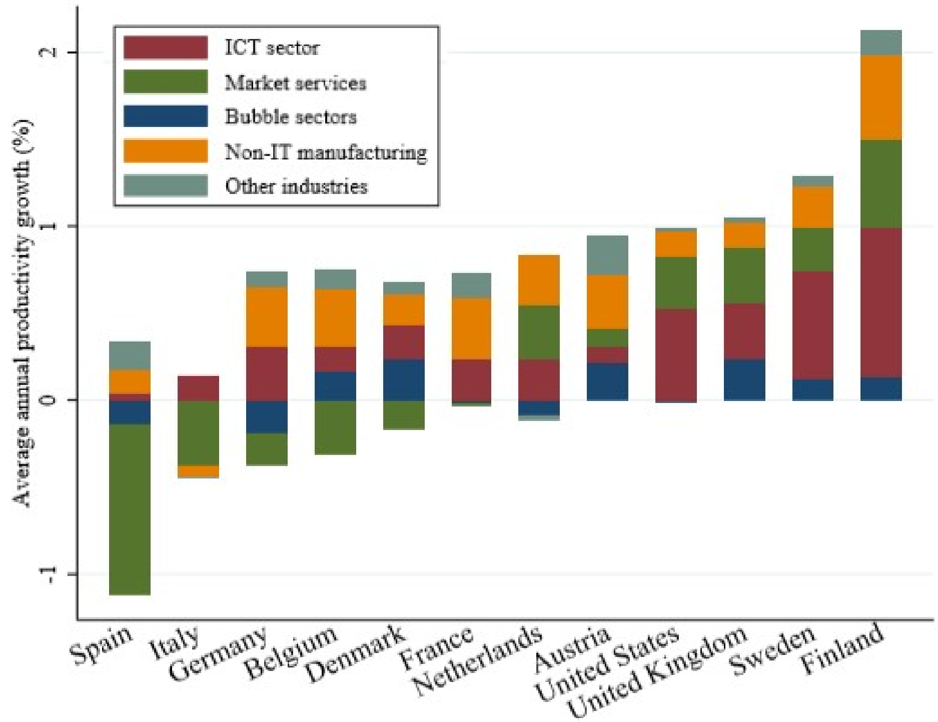
For the 1995–2007 period, the contribution of TFP growth in market services (such as wholesale and retail trade) was a key distinguisher between strong- and weak-productivity-growth countries. This is essentially the "original EU KLEMS story" of Timmer *et al.* (2010). In Spain and Italy, the contribution of market services was particularly negative, making overall TFP growth negative. This is the case even though many observers point to the shift towards low-productivity construction in the case of Spain; but construction (together with finance) was only a small direct negative contributor. In Germany, the contribution of market services was also negative, and in France it was negligible. In contrast, countries towards the right-hand side of the chart tended to have strong contributions from market services.

What's the story here? Think about distribution. Walmart and Costco and similar firms were much better than competitors at using ICT to manage their distribution systems and reorganizing their firms to do so. They were so much more efficient and expanded rapidly while competitors closed or downsized. Reallocation towards firms with high levels of productivity, and away from inefficient 'Mom and Pops' stores, drove productivity gains (e.g. Foster, Haltiwanger and Krizan, 2006, for evidence for the United States). In some countries, this sort of reorganization of the distribution sector was easier than in others. These differences then show up in the bar chart.

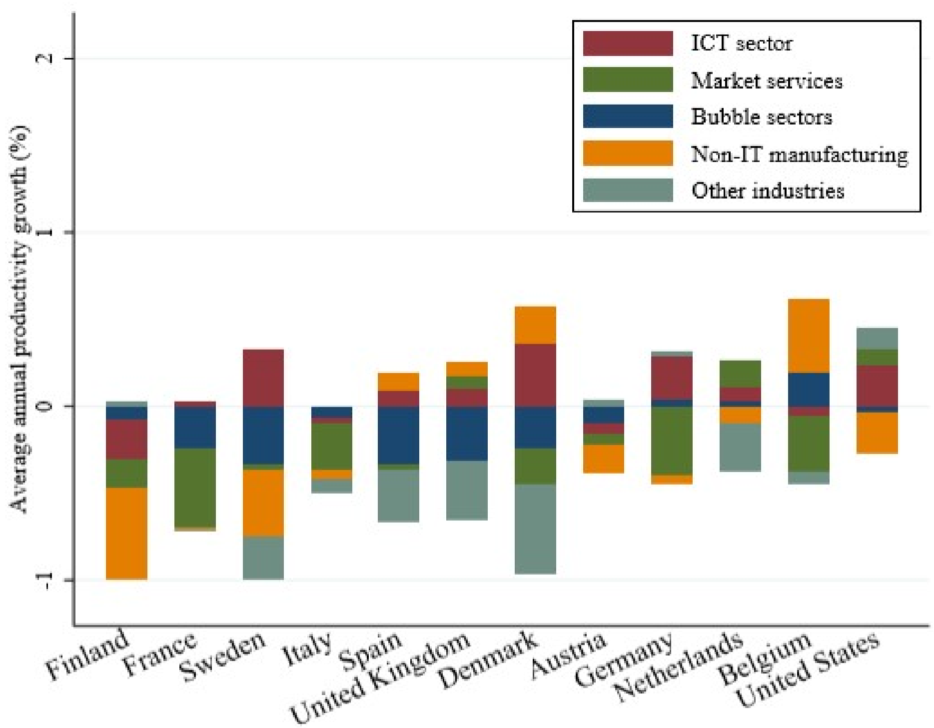
The pre-2007 contribution of industry groupings other than market services were more heterogeneous across countries and less consistently linked to strong versus

Chart 4: Sources of TFP growth by Industry Group (percentage point contributions)

Panel A: 1995-2007



Panel B: 2007-2015



Source: EU KLEMS 2017.
Note: ICT sector covers ICT goods and services, bubble sectors are finance and construction, other industries are agriculture, mining and utilities.

weak overall performance. Of course, the countries towards the right of the panel typically received more of a direct contribution from ICT goods and services. But that contribution was positive everywhere.

From 2007–15, the industry pattern across countries is more mixed. The main feature is that overall growth has been anemic, and often negative, with no clear smoking gun in the industry data. With the exception of Spain and Italy — where TFP growth was marginally less negative — countries had weaker TFP growth in the 2007-15 period than in the preceding decade. (The negative growth rates are more pronounced by ending in 2015, which is too early to be sure of a complete rebound from the double-dip European recession. In EU KLEMS 2019, PWT, or OECD data, the post 2015 period showed a more consistent return to positive TFP growth in most countries.)

This industry grouping was chosen primarily to illustrate how market services, the main factor in accounting for differences in country TFP growth from the mid-1990s to the mid-2000s, is no longer useful to understand growth differences since the Great Recession. Inklaar, Jäger, O'Mahony and van Ark (2020) consider a range of alternative industry groupings, including intensive ICT users and intensive users of intangible capital. They find that both the average market economy TFP growth from 1995–2015 and the change in growth after 2005 (within this period) is most closely matched by the growth and change in growth of ICT-intensive and intangibles-intensive industries. This leaves unanswered *why* industries that intensively use ICT and intangibles showed slower growth since 2007.

The takeaways from this section are that TFP is the right place to look for understanding weak labour productivity growth in Europe; that the pace was slowing, and between-country heterogeneity in productivity growth trends was rising, even before the Great Recession; and that stories that focus on particular sectors in particular countries (e.g. construction in Spain) won't explain the broad-based slow pace of TFP growth.

Evidence from Break Tests

We use aggregate data to explore the two hypotheses of a pre-recession slowdown in trend versus a crisis-induced break in trend. These two hypotheses are not mutually exclusive. For example, even if the trend were slowing (as shown in Section 1), it is possible that in some or many countries, the recession itself might then have been an important additional contributor to the slowdown in growth. The experience could differ across countries depending on factors such as the depth of the downturn, the sectoral composition of production, and the degree to which the financial sector was impaired in the country.

As noted in the introduction, there is some evidence that deep recessions (financially related or otherwise) might permanently lower the level of GDP relative to its pre-recession trend (e.g. Cerra and Saxena, 2008, Martin *et al.*, 2015, Blanchard *et al.*, 2015, Fatás and Summers, 2018).

Nevertheless, there is less evidence for *advanced* economies that the level or growth rate of *TFP* is permanently affected by recessions. For example, the 1930s Great Depression appeared to be an extraordinarily innovative period.[19] More broadly, Oulton and Sebastiá-Barriel (2017) look at growth-accounting variables following financial crises. They find that, for advanced economies, the long-run level of TFP is typically *not* significantly affected. In their estimates, advanced-economy GDP per capita is permanently lower after a financial crisis because employment per capita is permanently lower, whereas capital per worker as well as TFP are unchanged.[20]

For developing economies, or for the sample that includes all countries, Oulton and Sebastiá-Barriel (2017) do find that financial crises appear to permanently reduce both TFP and capital per worker, as well as employment per capita. Oulton and Sebastiá-Barriel's data end in 2010, so updated data might show more of an effect. Furceri and Mourougane (2012) discuss GDP effects through hysteresis in labour markets or persistent effects on capital deepening if there are changes in risk premia. They also find that impact of financial crises varies according to structural features such as the degree of openness, macro-economic imbalances, financial deepening, and the quality of governance. Relatedly, Jordà *et al.* (2020) find that monetary contractions typically have long-lasting effects on TFP and capital deepening.

The facts from Chart 1 and Section 1 — that TFP growth was already lower before the crisis in many countries — are somewhat consistent with the view that the effects of crises on advanced economy TFP may be small. That said, the Great Recession could have had an additional effect, as suggested by the step-down in the level of northern-European TFP visible in Chart 3.[21]

Table 2 shows the result of break tests on U.S. and European market-sector TFP growth. The data are from EU KLEMS (2012, 2017) for the market sector for the period 1980–2015. In all cases, the tests consider the null of a constant mean growth rate in TFP against the alternative of one or more breaks in mean growth. Since growth rates are generally declining, the tests are somewhat biased towards finding changes in trend.

The first two columns of the table allow for a break or breaks in TFP growth at an

19 Field (2003) and Alexopoulos and Cohen (2009) argue that the 1930s were the single most innovative U.S. decade of the 20th century. Gordon (2016) and Bakker *et al.* (2019) provide (different) updated time series estimates of U.S. TFP growth to argue that, while the 1930s were an innovative period (with faster TFP growth than the decades preceding it), it was less innovative than the decades that followed (during and immediately after World War II).

20 In standard neoclassical growth models, a permanent change in the level of employment would not affect steady-state capital per worker. Of course, changes in risk premia or other factors affecting the relative cost of capital to labour would affect capital per worker.

21 Without a formal model, we cannot say what would have happened to the path of global or country-level TFP in the absence of the Great Recession. Anzoategui *et al.* (2019) estimate a model where aggregate technology is endogenous to the cycle. According to their estimates, the Great Recession did, indeed, lower the path of TFP. For our purposes, the important point is that it is not an either/or discussion.

Table 2: Tests for Breaks in Market-Sector TFP Growth, 1980-2015

Country	Quant Likelihood Ratio (Sup Wald) Test: 1 break	Quant Likelihood Ratio (Sup Wald) Test: 2 breaks	Chow test for break after 2007	Chow test for break Relative to United States after 2007
United States	0.40	0.51	0.25	
	2006	1998 2005		
Europe	0.10	0.33	0.03	0.43
	2007	1990 2007		
Northern Europe	0.05	0.21	0.01	0.25
	2007	1990 2007		
Southern Europe	0.20	0.28	0.22	0.94
	2007	1991 2007		
Germany	0.27	0.16	0.23	0.67
	2007	2001 2009		
France	0.09	0.24	0.00	0.11
	2000	1989 2007		
Netherlands	0.55	0.25	0.19	0.88
	2007	1999 2007		
United Kingdom	0.13	0.27	0.01	0.16
	2007	1987 2007		
Spain	0.10	0.31	0.42	0.80
	1988	1988 2009		
Italy	0.40	0.33	0.29	0.88
	2000	2000 2009		

Note: A first set of numbers for each country or region are p-values against the null of a constant mean and are heteroskedasticity and autocorrelation robust. Second set of numbers are estimated dates after which the mean changes. TFP growth is annual data for the market sector from EU-KLEMS (2012, 2017). For estimation details of the Quandt tests, see Fernald, Hall, Stock, and Watson (2017).

unknown date.[22] For Northern European countries, the estimated break dates in the first column (the second row of numbers for each country) are usually around the beginning of the Great Recession. The strongest evidence is for a Northern European aggregate, where we find a significant break at the 5 per cent level after 2007. This is consistent with the view that the trajectory of TFP growth has been different since the Great Recession.

The results for individual countries are less strong. Only France has a p-value below 10 per cent — but the apparent break takes place in 2000, well before the recession. For the U.K. the test points to a break after 2007, albeit with a p-value of only 13 percent.

Nevertheless, as noted, the Great Recession was a sharp and distinct event. So, Chow tests — testing for a break at a known date — might make sense. Chow tests suggest stronger evidence of a break after 2007 in Northern Europe, especially in France and the United Kingdom.

Given the finding in the literature regarding a U.S. pre-Great Recession slowdown in TFP growth, another useful perspective is to ask whether there is any evidence of a break in TFP relative to the United States around the Great Recession. The answer (given by the final column) is no.

Interestingly, in the EU KLEMS data,

22 In all cases, we assume that aggregate TFP is a random walk and test for changes in the constant (the drift term). The estimation was done in Matlab following the approach in Fernald *et al.* (2017, Table 6). Allowing for a third break always led to a lower p-value than allowing for one or two breaks. The estimated third break date was almost always the same as the second break date shown when we allow for two breaks. Any aggregate breaks presumably reflect breaks in the underlying industry data — and a sectoral analysis might provide further insight or evidence. We leave that analysis for future research.

there is no evidence of significant breaks in the US data. Fernald *et al.* (2017) find stronger statistical evidence for a speed-up in U.S. TFP growth in the mid-1990s and a slowdown by 2006 or before. Fernald (2015) and Fernald *et al.* (2017) find that the timing of the mid-2000s slowdown was clearly prior to the Great Recession itself. (The datasets are different, as is the frequency.)

In conclusion, this analysis suggests the 2007–08 GFC may have had a negative effect on TFP growth rates in Northern Europe in addition to the slowing trend that we found for the earlier period. The evidence is far from conclusive. For one thing, other datasets show less strong results. Notably, the PWT data, which run through 2017, look qualitatively similar but with less statistical significance. For example, the p-value for northern Europe is only 16 per cent, rather than 5 per cent in the EU KLEMS data. More broadly, it is challenging to distinguish a gradually declining trend from a distinctive break in the time series. There is only mixed evidence for individual countries, and there is little evidence for breaks relative to the United States — where the break occurred earlier in the 2000s. Finally, for Southern Europe (Italy and Spain), the analysis suggests an earlier break date, consistent with the visual evidence from Chart 3.

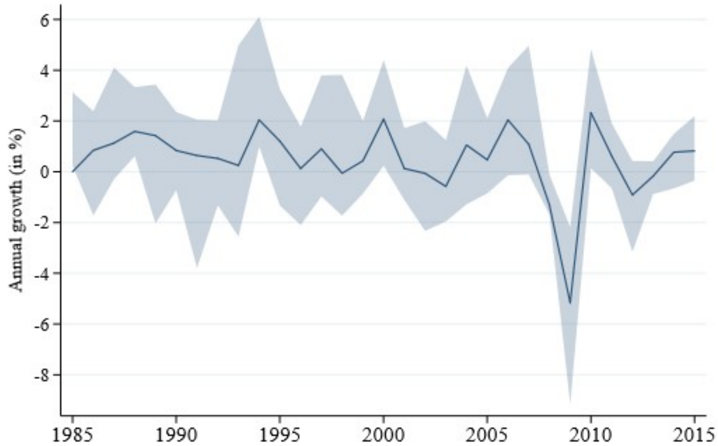
Cyclical Dynamics and the Role of the Great Recession

A challenge in disentangling productivity trends is the magnitude of the Great Recession itself. Considerable literature, mainly on U.S. data, has explored the cyclical properties of productivity — documenting that measured productivity can move substantially over the business cycle (see Fernald and Wang (2016) for a survey). To understand what we are seeking to "filter out", this section explores the role of cyclical dynamics for measured TFP growth. Given the distinctiveness of the GFC and the impact of the subsequent European debt crisis, it is hard to give a purely structural (as opposed to a cyclical) interpretation to TFP growth rate developments. But at the same time, the length of time since the GFC starts to favor a structural interpretation.

Chart 5 shows TFP growth for the 11 European countries in EU KLEMS 2017. The solid line is a GDP-weighted average for the market economy, with the shaded area denoting the lowest and highest growth rate in each year. In all countries, TFP growth fell sharply in the depths of the Great Recession. TFP growth rebounded in 2010, with the rebound inversely proportional to the decline.

The specific experiences of Germany and Spain are informative about the underlying features of the cyclical swing in TFP. The TFP decline in 2009 and rebound in 2010 were sharpest in Germany. Bellman *et al.* (2016) document that institutions in Germany (such as short-time work) encouraged use of the intensive margin (hours per worker, and perhaps effort per hour) rather than the extensive margin of hiring and firing. They also point out that economic conditions and business expectations in Germany supported the use of the intensive margin. For example, manufacturing surveys show that businesses thought the downturn would be temporary, so they

Chart 5: Range of Market Sector TFP Growth in Europe, 1985-2015



Source: EU KLEMS 2017, combined with EU KLEMS 2012.
Note: The solid line shows GDP-weighted average market economy TFP growth for Austria, Belgium, FInland, France, Germany, Italy, SPain, Netherlands and United Kingdom. The shaded area spans the minimum and maximum growth rate observed in each year in this set of countries.

had an incentive to hold onto workers they would want in the recovery (Bellman *et al.*, 2016:206; see also Fernald, 2018, for a review of the volume in which this paper appeared).

Spain, in contrast, saw the smallest TFP decline in 2009 and the smallest rebound in 2010. That is, TFP growth was only slightly procyclical. As Hospido *et al.* (2016) argue, firms disproportionately used the extensive margin of labour-input adjustment, in part because of a high share of workers on temporary contracts. In addition, Spanish firms were, in general, covered by collective agreements at a sector level that specified hours of work, making it harder to use that intensity margin. Thus, the strong responsiveness of employment/unemployment to output, and the limited response of TFP from the use of the intensity margin, is not surprising. Interestingly, in terms of trend, Spain's TFP growth was negative before the recession and for most of the period since. TFP growth only turned positive after the recovery in GDP growth in 2014.

Of course, as many observers have noted, Spanish labour productivity (output per hour) did look quite different — it rose in 2009 and was relatively strong for the next few years. This short-term disconnect between the performance of TFP and labour productivity is consistent with standard growth accounting. TFP is typically procyclical (because of cyclical factor utilization). But cyclical forces affecting capital deepening and labour composition (the other components of the two labour-productivity decompositions in equations 2 and 3) are countercyclical. As we discussed in the context of Panel A of Chart 2, the capital-output ratio is strongly countercyclical. In addition, low-productivity workers tend to lose their jobs at disproportionate rates in recessions, leading to positive contributions from labour compositions. So, in the absence of strongly procyclical TFP growth, labour productivity will be countercyclical — consistent with Spain's experience.

Have the cyclical forces completely played out in the European data? In the

U.S. context, Fernald (2014b) argues that by the end of 2010, the major cyclical dynamics on U.S. TFP from variation in the intensity of labour and capital utilization had played out. Thus, his estimates suggest the utilization margin recovers quickly, consistent with the burst in European TFP growth in 2010 that is visible in Chart 5.

However, Europe had a double-dip recession from 2011 to 2013, with a subdued recovery for several years thereafter. Hence, the cyclical effects on TFP may not have entirely played out by 2015 (the end year in EU KLEMS 2017). Consistent with this view, in PWT and OECD data, TFP growth was relatively strong in the post-2015 period (to 2017 in PWT and to 2018 in OECD), as was quarterly data on output per hour from Eurostat through 2017.[23] (Output per hour in 2018 and 2019 was more modest, consistent with the cyclical effects having run their course.) Our tentative conclusion is thus that by the end of the PWT sample period in 2017, residual cyclical dynamics from labour hoarding and low capital utilization are probably not central to the story. Cyclical effects may be more important in the post-2007 EU KLEMS growth rates. That is, rising factor utilization, which boosts measured TFP growth during the recovery period, may not have picked up sufficiently to offset the decline in utilization (and measured TFP) that took place during the recession period. Still, the trends in that dataset are broadly consistent with the trends in other datasets, suggesting that the main post-2007 trends were structural.

Measurement and Related Issues

Based on our analysis of aggregate and industry-level TFP growth, we have argued that TFP growth across European countries had been trending downwards for a substantial period of time before the GFC and, possibly, was subject to a further downward shift due to the GFC, both of which are unlikely to be affected to a great degree by cyclical dynamics. Yet that does not imply that that exogenous technological factors or resource allocation are the sole explanatory factors. Here, we consider several measurement and other issues that could be affecting our estimates of factor growth and TFP. Specifically, we consider issues related to capital measurement, demographics, market power, and intangible capital. We do not find that any of them can explain the TFP slowdown observed in the data.

Vintage Capital

The first measurement issue involves vintage capital. Going back at least to the 1950s, economists have argued that technology is often embodied in capital.[24] The embodiment logic suggests that the de-

23 http://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=tipsna71. We would also note that a renewed cyclical recovery is not visible in Euro-area TFP growth in the Conference Board's Total Economy Database or in OECD data, both of which run through 2018.

24 Key early contributions were Johansen (1959) and Solow (1960). Boucekkine *et al.* (2011) provide a recent survey that links the earlier literature with the more recent literature on investment-specific technical change.

cline in the investment rate might, on its own, reduce TFP growth. In recent decades, a common, and straightforward, modeling framework for embodiment has been the "investment-specific technical change" setup of Greenwood, Hercowitz, and Krusell (GHK) (Greenwood *et al.*, 1997). Although not always presented this way, the GHK framework is equivalent to a two-sector model, where one sector produces capital goods and the other consumption goods (Oulton, 2007). An important assumption in implementing this framework is that the improved quality of new vintages of capital is measured as a lower price for new capital goods. That lower price, in turn, implies that any given nominal spending on capital goods is associated with a higher real quantity of capital goods, and a higher level of TFP in capital-goods production.

In the GHK framework, if firms reduce their investment spending, then the "new and improved" capital is not installed. In terms of aggregate TFP, there is a lower weight on the presumably faster-TFP-growth investment sector. To investigate the potential importance of this channel, we recalculated market-sector TFP growth under the assumption that industry weights remained fixed at their 2007 level. The benchmark, of course, allows the weights to change. If the falling investment share meant there was a lower weight on fast TFP growth equipment-producing industries, then TFP growth should be stronger when using pre-GFC shares. The constant pre-GFC weights turn out to make little difference. In fact, TFP growth from 2007–15 is a few basis points *worse* than the actual data. The reason the weights do not matter much is that every sector (including the ICT sector and non-IT manufacturing) had low TFP growth. Thus, at least with this interpretation of the vintage-capital argument, it is unlikely to be an important explanation for the decline in TFP.

Demographics

A related, but distinct, argument is that an aging, and slower growing, population might contribute to slower TFP growth. For example, in the EU-15, growth of the "working age population" (aged 15-64) slowed from 0.5 per cent per year from 2000–07 to only 0.1 per cent per year from 2007–18. There are a range of channels through which an aging population might affect TFP growth. These include skills that depreciate, reduced managerial talent (Feyrer, 2007), reduced dynamism and labour mobility (e.g. Karahan, Pugsley, and Şahin 2019), and greater resistance of older workers to innovation.[25]

Based on cross-country panel regressions for European countries, Aiyar and

25 See Acemoglu and Restrepo (2017) for further references. This is, at least in part, a measurement issue, since these factors could, in principle, be picked up in labour composition measures that control for age or experience. For the United States, labour composition measures (including by the Bureau of Labor Statistics and in Fernald, 2014), control for age/experience. But in EU KLEMS and the PWT that we use in this article, the labour composition adjustment controls for education alone. That said, the effect of age/experience on labour services can be more subtle if learning on-the-job and vintage effects in human capital are taken into account (Inklaar and Papakonstantinou, 2020).

Ebeke (2016) predict that an aging European workforce could reduce TFP growth in Europe by about 0.2 percentage points per year from 2014 to 2035. This compares with a drag from aging of only about 0.1 percentage points from 1985 to 2007. Thus, the Aiyar-Ebeke study suggests that aging might have contributed modestly — around 0.1 percentage points — to the overall post-GFC slowdown in TFP growth.

Aging could also affect capital deepening, though the effects are less clear. One argument is that slower growth in the working age population could reduce capital growth — as it does in neoclassical models — thereby leading to slower introduction of new capital vintages. As noted above, we are not persuaded this vintage effect is a significant factor in the data. In addition, Acemoglu and Restrepo (2017) argue that an aging population, which reduces labour supply, may endogenously lead to an increase in automation that offsets the negative effect on productivity growth. They find that countries that are experiencing more rapid aging are also adopting robots more intensively, which might raise TFP growth as well as capital deepening (Graetz and Michaels, 2018)

On balance, we view an aging, and slower growing, population, as having a small, probably negative, effect on TFP growth at this point. Still, there is no question that demographic changes are going to be enormously important in shaping the world in decades to come. Fernald and Jones (2014) for example, highlight the implications of semi-endogenous growth models such as Jones (2002). In that model, long-run growth comes from the discovery of new ideas which, in turn, come from people. Slower *global* population growth (in countries at the research frontier) implies slower discovery of new ideas, and reduced TFP growth.

That said, the timing of the TFP slowdown is unclear. Jones (2002) argues that the effect has been offset by increased research intensity. In addition, Fernald and Jones (2014) argue that, as China, India, Korea, and other countries become important research centers, the "effective population" looking for new ideas has grown. The important takeaway from this line of research is that demographics are an important global force that can affect productivity, even if the effects, and the timing, can be subtle.

Market Power and Intangibles

Two further issues that have received a lot of attention in recent literature are an apparent rise in market power, and the increasing share of intangibles in investment and output. We find little evidence so far that either of these stories can explain the slowdown in aggregate European productivity growth — at least in a direct sense.

As Karabarbounas and Neiman (2018), among others, point out, rising market power and rising intangibles could both explain apparently increasing economic profits in the data (what Karabarbounas and Neiman call "factorless income"). The link can be direct when rising market power leads to pure economic profits. It does not need to, if the rising market power is needed to offset rising returns to scale, say, from fixed costs.[26] With intangibles, the issue is that the returns to intangibles show up in residual payments to capital, but our usual measures of the capital stock might not include those intangibles. Concretely, Apple had a market capitalization of $1.4 trillion in late January 2019, but it has few tangible assets. Its cash flow derives from a return on its enormous stock of intangible design and marketing skills.

Both stories have implications for measuring innovation, as well. First, if there are pure economic profits, then the typical default of estimating capital's factor share as a residual is misleading — that residual includes pure profits as well as the implicit rental cost of capital services. Second, if the story is rising (unmeasured) intangibles, that has implications for measurement of both output (producing the intangible assets) and inputs (the accumulated intangibles stock).

Chart 6 takes a first look at this story by looking at the implicit internal rate of return to measured capital in the EU KLEMS dataset. That is, for each country, there is an implicit nominal return in the user-cost formulas (with one user cost equation for each type of capital) such that the sum of the implicit capital rental payments exhausts non-labour factor costs in value added. To adjust for inflation and for the overall level of interest rates, we subtract the nominal government bond yield. The rates in the chart just can be interpreted as reflecting risk, financial frictions — or pure profits.[27]

In Chart 6, 7 out of the 10 countries shown saw an increase in this premium over the sample period. This increase could be consistent with rising economic profits. That said, the evidence is not conclusive, in that of the five largest European economies, only Germany and the U.K. saw an increase; France, Spain, and Italy did not.

Still, if we interpret rising internal rates of return as reflecting rising market power, it would imply that measured TFP growth did not necessarily track innovation and technology. In the simplest case of constant returns, the issue is that we are underweighting labour and overweighting capital. One could investigate this directly by imposing a premium over the government bond rate in calculating implicit rental cost.

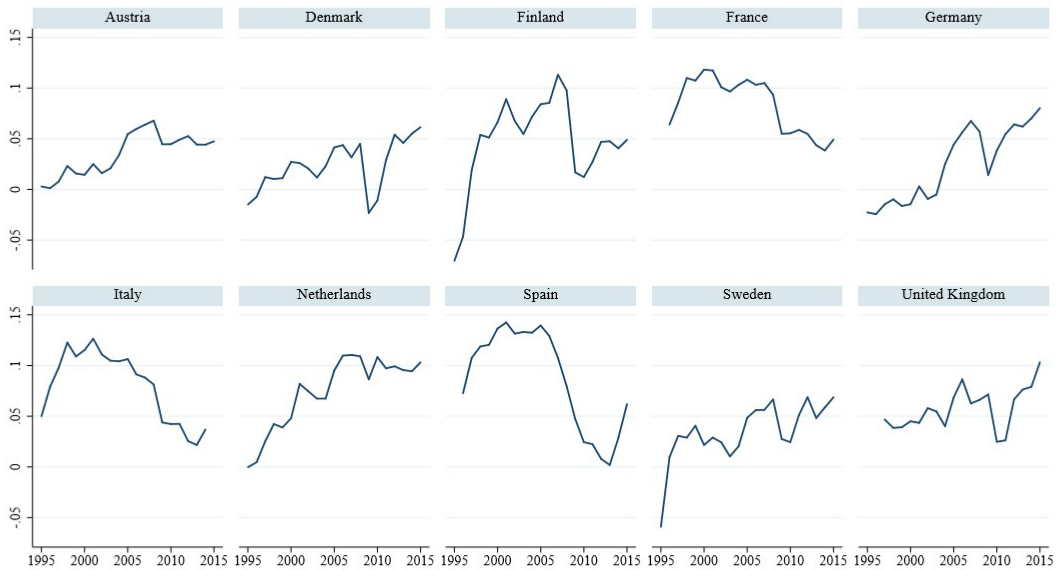
We have not done that, but as a first test, we can see how large a difference it would make to shift weight towards labour and away from capital. Specifically, as a benchmark, we simply impose that because of rising economic profits, the true capital share of value added revenue falls 10 percentage points after 2005 — a quite large effect — with labour's share rising 10 per-

26 Ho and Ruzic (2020) find, for U.S. manufacturing plants, that profit rates are rising despite constant markups. In their estimates, returns to scale have fallen over time.

27 Analysing the overall labour or capital share is subject to an even longer list of potential alternative explanatory factors. See also Barkai (2020) for a related approach for US data.

28 This is only to gauge the plausible magnitude of the effect. With markups, other issues arise, including the fact that aggregate technology cannot in general be expressed just as a function of aggregate output and aggregate capital and labour. The distribution of output and inputs across firms and industries also matters. See, for example, Basu and Fernald (2002).

Chart 6: Rate of Return to Capital in European Countries



Source: EU KLEMS 2017, calculations by Daan Freeman. Government bond yields: ECB.
Note: The rate of return is defined as the internal rate of return on fixed assets minus the 10-year government bond yield.

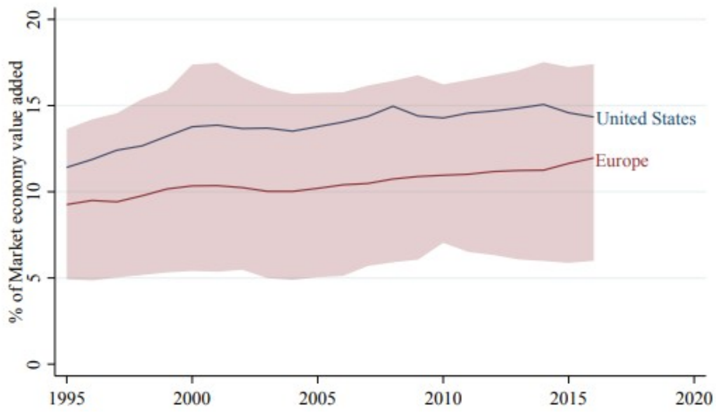
centage points.[28] Under the assumption of constant returns, this increases the implied growth rate of aggregate technology by $0.1 \times (\Delta\ln K_t - \Delta\ln H_t)$.

In EU KLEMS data, many countries did see faster growth of capital than labour since 2005, so the adjustment would raise technology growth. But the magnitude is typically no more than 0.1 percentage point, and often smaller. It is larger in the case of Spain, about 0.2 percentage points, since capital input kept rising even as labour fell from 2005 to 2015; but Spain was *not* a case where there is evidence of a rising internal rate of return. Our conclusion is that rising market power probably cannot, through measurement channels, explain weak measured TFP growth.

Non-constant returns to scale could also matter, since output elasticities differ from factor shares. With increasing returns to scale ($\gamma > 1$, where γ is the degree of returns to scale), measured TFP growth will mechanically fall if share-weighted input growth, $\Delta\ln(X)$, falls. In PWT, share-weighted capital and labour growth slowed by 1.1 per cent from 1995-07 to 2007-17. If the typical industry γ were 1.1, then TFP growth would fall by about 0.1 percentage point through this effect. That said, most estimates suggest that returns to scale γ are not too far from one (e.g. Basu and Fernald, 1997, and Inklaar, 2007). Hence, this estimate is probably an upper bound.

Another interpretation of Chart 6 is that it is capturing intangible investments. Indeed, one channel through which a recession might cast long shadows is through reduced intangible investments — that is, reduced investments in the future. Some of these investments are measured in the national accounts, but others are not. As a pure measurement issue, if intangibles are not measured, there is missing investment output as well as missing intangible capital input.

Chart 7: Importance of Intangible Investment in the United States and Europe, 1995-2016



Source: INTAN-Invest Databse, January 2019, Corrado *et al.* (2016).
Note: European countries covered are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and UK. Red area indicates the range of investment rates and the solid red line is the weighted average European productivity level. Ireland is omitted from the European range as its R&D investment increased by a factor of 5.5 between 2014 and 2016, leading to an investment rate of 32 per cent in that year. Eurostat investment data show the R&D investment rate for Ireland returns to below their 2015 level by 2018.

The intuition is clear. Chart 7 looks at the share of intangible investments relative to market-sector value added. Intangibles here are as measured in the INTAN-Invest database of January 2019 (Corrado *et al.*, 2017), which attempts to quantify many of the harder-to-measure types of intangibles (organizational change, training, and branding, for example). The intangibles share has been rising in virtually all countries, but there is no obvious change in trend before and after 2005. The 2019 vintage of EU KLEMS (Stehrer, 2019) includes a set of growth accounts that incorporates a much broader set of intangibles than are in the national accounts, using a similar measurement approach as the INTAN-Invest database. These intangible assets include various forms of innovative property and "economic competencies" (e.g. training, advertising, market research, and organizational capital). Table 2 in the online Data Appendix shows that the growth accounting is only modestly affected by including this much broader set of capital. So as with direct measures reflecting market power, there is no clear evidence that changing intangible investment rates can account (in a direct sense) for the slowdown in TFP growth.

As a caveat, this argument captures only the direct effect of intangibles on the accounting. The indirect effects are less clear. For example, Corrado *et al.* find a similar result for the direct growth-accounting effects. However, they argue that spillovers to growth from the accumulated stock of intangibles can explain much of the mid-2000s U.S. TFP slowdown. To obtain this result, they assume very large and immediate positive spillovers from a broad class of intangibles — well beyond R&D — such as advertising, training, and organizational capital. We are less persuaded that spillovers to this large class of intangibles is as large as assumed by Corrado *et al.* (2019). For example, the argument for spillovers from organization capital are weaker than for R&D as organization capital tends to be more tacit, and the evidence is likewise weaker (e.g. Chen and Inklaar, 2016). We discuss additional indirect channels for intangibles to matter in the next section.

Discussion and Implications for the Future

European labour productivity and TFP growth is notably lower than it was 20 to 30 years ago. As in the United States since the mid-2000s, there is evidence of a declining trend before the Global Financial Crisis. In Europe, we find some mixed evidence that the crisis itself might have further dented productivity growth prospects[29].

Fernald (2014b) emphasizes that the U.S. slowdown was focused in IT-producing and IT-intensive industries, arguing that the slow pace of growth reflected the incremental gains of the IT revolution for broad swaths of the economy (see also Gordon, 2016). A closely related view is that ideas are becoming harder to find (Bloom *et al.*, 2020).

Arguably, the same story applies to Europe. European TFP growth has been slowing since the 1960s (Chart 1), and the slow pace of the past decade looks like a continuation of that trend. Indeed, as Chart 3 showed, the remarkable fact for Northern Europe has been the rough stability since the 1990s in TFP levels relative to the United States. The visual evidence from Chart 3, along with the mixed evidence from formal break tests, suggest that stories in which the Great Recession caused the slow pace of productivity growth are at best incomplete.

Still, the striking feature of Chart 3 is that, for decades, European productivity has either been diverging from the frontier (Spain or Italy) or else stopped converging short of the frontier (Northern Europe). These same challenges were highlighted by the pre-recession comparative U.S.-Europe literature. That earlier literature (e.g. Timmer *et al.*, 2010, 2011) highlighted the challenges in adapting to a knowledge-based economy, in terms of its demands on skills, innovation, management, and organizational change.

It has long been argued that product, labour and financial market reforms are crucial for improving its productivity growth; this is, for example, the Bartelsman (2013) view that Europe has the potential for quite fast productivity growth by converging (in institutions and, ultimately, in economic outcomes) to U.S. levels. This view calls for ambitious structural reforms in many European economies to reverse anti-competitive regulations on labour and product markets and to reduce the importance of financial frictions. Yet as pointed out by Philippon (2019), the argument that the United States is a beacon of free-market dynamism and innovativeness that every European country should aspire to emulate is harder to square with evidence for the U.S. of concentrating markets, rising costs in important sectors such

29 This paper has not discussed why Europe might look worse. One possible reason is that fiscal and monetary policy responded less aggressively in Europe than in the United States, allowing the cyclical to become structural.

as education and healthcare, and reduced business dynamism. At the same time, European countries have substantially liberalized their product markets. In 1995, nearly all European countries had more restrictive regulations in place than the United States, while by 2008 most were less restrictive than the United States (Philippon 2019:126). At the very least, a simple 'reform and productivity will follow' conclusion is not warranted by these trends.

This article has focused on data and growth accounting. Stepping back, some (complementary) theoretical models suggest that a slowing global productivity trend might reflect changes to the process of innovation. In particular, several recent articles highlight how information technology itself might endogenously lead to a slower pace of innovation and growth throughout the economy. These stories put the slowing European and U.S. productivity trend in the context of other recent developments, such as declining dynamism, rising dispersion of firm-level productivity in many countries (e.g. Andrews, *et al.*, 2019), and the growing importance of superstar firms (Autor *et al.* 2019).

For example, de Ridder (2019) argues that intangibles linked to IT hardware and software are a form of fixed costs. Successful firms expand, which allows them to spread these fixed costs over more production. The initial expansion of these successful high-intangible firms, in turn, increases productivity growth even as concentration rates rise. But over time, another effect dominates: it is challenging (for new entrants or for existing low-intangible incumbents) to compete with the high-intangibles incumbent. So innovative activity, firm turnover, and aggregate productivity growth slow.

Aghion *et al.* (2019) provide a related endogenous growth argument linked to information technology. In their story, improvements in information technology initially boosts productivity by increasing managerial scope, which allows high-productivity/high-markup firms to expand. But the expansion of these high-productivity firms eventually deters innovation and undermines long-run growth. The reason is that potential innovators would have to compete with a high-productivity firm. That prospect lowers the expected the returns to innovation. Though the de Ridder and Aghion *et al.* stories differ substantially in their details, both suggest indirect reasons for why information technology — a general purpose technology — might now be leading to reduced innovative activity at the frontiers of the global economy.[30]

Certainly, there is much research yet to be done on the changing nature of firm dynamics, as well as the degree to which those changes are, indeed, related to intangible capital and information technology. There is much to be learned about how these changes affect the process of convergence at a country level, and the degree to which policy choices can influence them. Nevertheless, until something changes, the

30 Andrews *et al.* (2019) find, in firm-level data, that frontier TFP growth slowed after about 2007. They emphasize, however, the growing dispersion between the "best firms" and the rest, which they interpret as a growing technology diffusion problem.

best guess is that slow trend growth is the new normal for Europe, just as it is for the United States.

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Data Appendix to "Does Disappointing European Productivity Growth Reflect a Slowing Trend? Weighing the Evidence and Assessing the Future"

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In the main text, we focus on the total economy from the Penn World Tables (PWT) and the market economy from EU KLEMS 2012+2017. This appendix discusses the variables we use in greater detail and compare results with several additional datasets. The additional datasets include (in Appendix Table 1) the EU KLEMS total economy, the OECD Productivity data, the Conference Board Total Economy Database, and (in Appendix Table 2) EU KLEMS 2019 (Stehrer, *et al.*, 2019).

1 The main article is available at http://www.csls.ca/ipm/38/Fernald.pdf.

Table 1: PWT Variables for Figures and Tables

Variable Description	Variable Code(s)
Chart 1	
TFP	*RTFPNA*
Weighting	$CGDP^o$
Table 1	
Labour Productivity (GDP per hour)	*RGDPNA / (EMP × AVH)*
Capital/Hour	*RKNA / (EMP × AVH)*
Labour Composition	*HC*
TFP	*RTFPNA*
Capital/Output	*RKNARGDPNA*
Weighting of GDP	$CGDP^o$
Weighting of Capital	(1 - LABSH) × $CGDP^o$
Weighting of Labour	LABSH × $CGDP^o$
Chart 2A	
Capital/Output	*RKNARGDPNA*
Weighting	$CGDP^o$
Chart 2B	
Investment/GDP	v_{gfcf}/v_{gdp} (NA data file)
Weighting	$CGDP^o$

We rely on PWT[2], version 9.1, along with further documentation. See Feenstra *et al.* (2015) for the overall documentation of the database. The variables we use are shown in the table above.

We combine the EU KLEMS releases of 2012 and 2017 to enable a longer time series analysis. We use the 2017 time series for however long available. For nearly all variables, we then use the 2012 time series for extrapolation to each available year t (country and industry subscripts are omitted for clarity):

$$\tilde{x}_{2017,t} = x_{2012,t} \times \frac{x_{2017,\tau}}{x_{2012,\tau}}$$

Here τ is the first year for which data are available in the 2017 release and x is the relevant variable, such as value added at current prices (*VA*) or the index for total factor productivity (*TFPva_I*). The only exceptions to the extrapolation in equation (*A1*) are the contributions to value added growth of hours worked (*VAConH*), of labor composition (*VAConLC*), of ICT capital (*VAConKIT*) and of non-ICT capital (*VAConKNIT*). For these variables, we use the 2012 values as given.

2 Available for download via www.ggdc.net/pwt.

Table 2: KLEMS Variables for Figures and Tables

Variable Description	Variable Code(s)
Table 1	
Labour Productivity	*VA_QI/H_EMP*
Capital/Hour	*CAP_QI/H_EMP*
Labour Composition	*LAB_QI/H_EMP*
TFP	Based on equation (1) in the main text
Capital/Output	*CAP_QI/VA_QI*
Weighting across Market Industries	*VA*
Weighting across Countries	See Appendix Table 1
Table 2, Chart 3, Chart 4, Chart 5	
TFP	Aggregate across industries (and countries) as for Table 1
Chart 6	
Internal Rate of Return	Computed based on capital input files, giving capital stocks, deflators and depreciation rates
Chart 7	
Weighting across Countries	$CGDP^o$

Table 3: Sources of Labour Productivity Growth in Europe Based on EU KLEMS, OECD, and The Conference Board Database

	1985-95	1995-07	2007-15	1995-00	2000-07	2007-11	2011-15
EU KLEMS Total Economy (combination of 2012 and 2017 version)							
(1) Labour productivity growth	2.18	1.41	0.45	1.64	1.25	0.35	0.54
Accounting decomp. 1 (p.p. contributions):							
(2) Capital/hour	1.14	0.80	0.43	0.94	0.70	0.61	0.26
(3) Labour composition	0.38	0.20	0.26	0.25	0.16	0.31	0.21
(4) TFP growth	0.65	0.42	-0.23	0.45	0.40	-0.57	0.10
Accounting decomp. 2 (p.p. contributions):							
(5) Capital/output	0.62	0.46	0.43	0.56	0.39	0.77	0.10
(6) Labour composition	0.57	0.31	0.40	0.39	0.25	0.48	0.32
(7) TFP growth	0.98	0.66	-0.37	0.70	0.62	-0.90	0.16
OECD							
	1985-95	1995-07	2007-17	1995-00	2000-07	2007-11	2011-17
(1) Labour productivity growth	2.04	1.61	0.60	1.82	1.45	0.36	0.76
Accounting decomp. 1 (p.p. contributions):							
(2) Capital/hour	1.01	0.72	0.50	0.75	0.70	0.72	0.35
(3) Labour composition							
(4) TFP growth	1.01	0.86	0.06	1.03	0.74	-0.48	0.41
Accounting decomp. 2 (p.p. contributions):							
(5) Capital/output	0.60	0.39	0.45	0.35	0.42	0.84	0.20
(6) Labour composition							
(7) TFP growth	1.42	1.17	0.08	1.41	1.00	-0.65	0.57
Total Economy Database (April 2019)							
	1990-95	1995-07	2007-17	1995-00	2000-07	2007-11	2011-17
(1) Labour productivity growth	2.48	1.49	0.56	1.76	1.30	0.41	0.66
Accounting decomp. 1 (p.p. contributions):							
(2) Capital/hour	1.34	0.82	0.61	0.78	0.85	0.98	0.37
(3) Labour composition	0.28	0.26	0.25	0.32	0.22	0.33	0.19
(4) TFP growth	0.88	0.42	-0.31	0.68	0.24	-0.91	0.09
Accounting decomp. 2 (p.p. contributions):							
(5) Capital/output	0.60	0.34	0.65	0.09	0.52	1.42	0.13
(6) Labour composition	0.46	0.45	0.43	0.54	0.38	0.58	0.34
(7) TFP growth	1.47	0.72	-0.54	1.16	0.41	-1.59	0.17

Note: Sample periods and country differ slightly across datasets.

Table 4: Source of Labour Productivity Growth Based on EU KLEMS Database With and Without Additional Intangibles

	(2) 1995-07	(3) 2007-17	(4) 1995-00	(5) 2000-07	(6) 2007-11	(7) 2011-17
EU KLEMS Total Economy (2019 version, only NA intangibles)						
(1) Labour productivity growth	1.46	0.55	1.71	1.29	0.42	0.64
Accounting decomp. 1 (p.p. contributions):						
(2) Capital/hour	0.41	0.27	0.44	0.38	0.51	0.11
(3) Labour composition	0.19	0.21	0.24	0.16	0.26	0.17
(4) TFP growth	0.87	0.07	1.03	0.76	-0.36	0.36
Accounting decomp. 2 (p.p. contributions):						
(5) Capital/output	-0.13	0.13	-0.19	-0.09	0.57	-0.17
(6) Labour composition	0.28	0.31	0.36	0.23	0.40	0.26
(7) TFP growth	1.32	0.11	1.55	1.16	-0.55	0.55
EU KLEMS Total Economy (2019 version, including additional intangibles)						
(1) Labour productivity growth	1.52	0.57	1.77	1.33	0.40	0.69
Accounting decomp. 1 (p.p. contributions):						
(2) Capital/hour	0.41	0.28	0.43	0.39	0.51	0.13
(3) Labour composition	0.19	0.21	0.24	0.16	0.26	0.17
(4) TFP growth	0.92	0.08	1.11	0.79	-0.37	0.38
Accounting decomp. 2 (p.p. contributions):						
(5) Capital/output	-0.16	0.14	-0.24	-0.10	0.58	-0.16
(6) Labour composition	0.28	0.31	0.36	0.23	0.40	0.26
(7) TFP growth	1.40	0.12	1.67	1.21	-0.58	0.59

Source: Stehrer *et al.* (2019). Data start in 1995. Top panel includes only national accounts intangibles in output and capital and is from the "statistical" tables. Bottom panel includes additional intangibles and is from the "analytical" tables.

The World Bank Perspective on Productivity: A Review Article on *Productivity Revisited: Shifting Paradigms in Analysis and Policy*

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Abstract

In *Productivity Revisited*, the World Bank turns its ongoing productivity research program to the issue of the apparent failure of productivity in developing countries to converge to the higher productivity in advanced economies. The World Bank asserts, but provides little evidence, that converge is not taking place The analysis is grounded in the so-called second wave of productivity research which uses firm-level data to disaggregate productivity into gains within firms, across firms through research allocation and through market entry and exit. The disaggregations are found to differ across countries, suggesting convergence policies may need to be shaped to local circumstances rather than generalized across developing countries. A common question arising throughout is why firms, sectors and economies do not do more to emulate the behaviours of the more productive counterparts in advanced economies. Considerable emphasis is placed on managers and entrepreneurs in developing countries not having the right skill set as they have inadequate education and are risk averse. Despite claims that second-wave analysis puts into question traditional policy prescriptions, the World Bank advocates a traditional set of policy recommendations involving creating favourable business conditions, reducing distortions and improving human capital.

Productivity accounts for much of the differences in GDP per capita across countries. Identifying policies to stimulate it is thus critical to alleviating poverty. Given the World Bank interest in the productivity issue, the organization has established the World Bank Productivity Project headed by the Equitable Growth, Finance and Institutions Group.

The project has released four reports to

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date, each which explores a different aspect of the productivity issue through dialogue with academics and policy makers, and through sponsored empirical work in the World Bank's client countries. The first report (Cirera and Maloney, 2017) dealt with innovation and technological catch-up. The two most recent reports have examined high-growth firms (Goswani *et al.*, 2019) and agricultural productivity (Fuglie *et al.*, 2020). The second volume, released in 2018, is the focus of this review article.

Productivity Revisited: Shifting Paradigms in Analysis and Policy, by Ana Paula Cusolito and William F. Maloney of the World Bank, is the latest document from the World Bank Productivity Project which "seeks to bring frontier thinking on the measurement and determinants of productivity, grounded in the developing-country context".[2] The focus is on the apparent failure of productivity in developing countries to converge toward the higher productivity in advanced economies. Yet considerable attention is paid to the slowdown in productivity growth in advanced economies. The document sheds little new light on the issue so this portion of the document will not be reviewed here.

Productivity Revisited makes some good points on the state and future of productivity research. It contains some nuggets of research results and sets out some logical policy reforms to bolster productivity in developed countries. As such, it is a welcome and valuable addition to the productivity literature. Yet it has flaws. Some can be worked through with considerable effort on the part of the reader including the distraction of starting with what is essentially a literature review on productivity developments in advanced economies. Other flaws are more difficult to overcome.

For a report dedicated to the convergence in productivity between developing and advanced economies, the reader might expect a lucid exposition of the data, with trends marked. *Productivity Revisited* is a disappointment in this regard. For example, the lead statement is the observation that average GDP per capita of the richest 10 per cent of countries in 2000 was 40 times higher than that of the poorest 10 per cent of countries. Not only is the observation dated by 2 decades, but it is a static observation and reveals nothing on the issue of convergence. This is followed by brief summaries of a few studies purporting to show divergence. One of the studies covers the last two centuries. Although the World Bank report does not state over what period there might have been an expectation of convergence, it is likely most were thinking of recent decades when the world economy seemed to be becoming more linked. Then there is a reference to a World Bank study showing a widening of late in productivity between southern and northern members of the European Union. These are not even the countries under examination in *Productivity Revisited*.

The reader is asked to take the authors' word that convergence has either stalled or even shifted to divergence and then follow

2 The publication is available without charge at https://openknowledge.worldbank.org/bitstream/handle/10986/30588/9781464813344.pdf?sequence=9&isAllowed=y.

them on the path to explanations and what to do about it. Or to find the data elsewhere. Skipping over the data precludes the analysis of certain questions. For example, it may be that convergence is easiest when the gap is largest but that inadequacies in infrastructure, capital and labour markets and policies make it more difficult to close smaller gaps. This could have been examined over time and cross-sectionally using the countries in the study.

The authors' claim that productivity in developing economies is not converging with productivity in advanced economies seems inconsistent with the strong growth rates in some of the larger emerging economies over recent decades. China and India are examples. Further, labour productivity is an important driver of this growth. It seems curious that these developments have not led to convergence. But then the reader does not know how the authors are defining convergence for developing economies. For example, are economies weighted by their size? If so, China and India would dominate the results of the study.

Such basic questions over the finding on convergence hang over the balance of the World Bank report. Yet the report does contain important research so despite the weakness in setting the context, the authors' approaches and results are still worthwhile examining.

Productivity Revisited is grounded in a conventional disaggregation of aggregate total factor productivity growth into three components or sources of growth: improved performance within firm; improved allocation of factors of production between firms and; improved entry and exit of firms. This firm-level dissagregation can presumably be applied at both the fsectoral and economy-wide levels. Possible sources of within firm productivity gains include managerial skills, workforce skills, innovation capacity and technology-absorption capacity. Improved allocation is associated with the reallocation of factors of production and economic activity toward more efficient firms. Productivity can be improved if high-productivity firms enter and low-productivity firms exit.

The authors argue that previous research has often mischaracterized the contribution of the various components. For example, the authors argue that claims of distortions in resource allocation may instead reflect adjustment lags, risk or differences in technology, quality markups, or even levels of experimentation. The observations seem to offer some promise for a "purer" form of future research. But at the same time, one should worry whether such distinctions could obscure the more basic question. That is, why do lower productivity firms not emulate the behaviour of higher productivity firms? It is not so much of interest that they have different production functions, but rather why they have different production functions. Further, the authors argue the three components are "inextricably linked" and they share many of the same, underlying factors. This should make one cautious of relying too much on analyzing productivity through the disaggregation. Perhaps one should instead look at the factors in common across the three components.

Productivity Revisited purports to present the "second wave" of productivity analysis. This is grounded in firm-level data and analysis with integration of human capital. The document argues that "second-wave analysis clearly increases the uncertainty surrounding some traditional recommendations". Yet with few qualifications, the fifth and final chapter advocates what seems like an inventory of traditional recommendations. This is not to argue that the recommendations are not valid. It would appear logical that developing countries need to establish favourable business conditions, reduce distortions, and improve human capital. The point is that it is not clear how such traditional recommendations flow from the research the World Bank describes in previous chapters.

This review article consist of four main sections. The first section discusses the application of the "second-wave" approach to productivity analysis. The second section looks at the World Bank policy prescription to boost productivity growth. The third section discuss what the World Bank might have done differently. The fourth and final section briefly reviews the Canadian experience in the area of firm-level productivity research.

Application of "Second-Wave Analysis" in *Productivity Revisited*

Productivity Revisited refers in general to developing economies as their subject, but a certain "representative" cross-sample is examined including Chile, China, Columbia, Ethiopia, India, Indonesia, Malaysia, and Mexico (there is as well a reference to using data from Taiwan and Thailand and Romania). It is claimed, but not shown, that the cross-sample is not demonstrating convergence in productivity level toward that of advanced economies. It is not clear whether this is true only in the aggregate of the cross-sample or as well for each economy [3].

The focus of the report is to disaggregate productivity growth into the components of growth within firms, across firms and through entry and exit. The first general observation that comes through loud and clear is that generalizations across the universe of developing economies cannot be made. For example, almost half of productivity growth in India is driven through resource reallocation between firms whereas this drives almost none of the productivity growth in Chile. Productivity growth within firms has been very important in China, Ethiopia, India and Malaysia but has had little impact in Columbia. If such distinctions are valid, then cracking the case of the failure to converge may need to proceed more on a country-by-country basis than by aggregating developing economies. But the World Bank authors do pose the question of whether such distinctions are valid.

The World Bank authors describe their report as the application of "second-wave analysis" to productivity growth and the issue of productivity convergence. This second wave is said to pull together "the un-

3 Wu *et al.* (2017) find that value added per employed for the total economy increased over the 1981-2011 period at an average annual rate of 8.0 per cent in China and 4.5 per cent in India. These growth rates were much faster than experienced in developed countries over the period and led to a convergence the labour productivity levels between China and India and the developed world.

derlying shifts in paradigm and measurement". It incorporates advances in the estimation of production functions and the quantification of human capital relevant to productivity improvements. A central feature is its grounding in a firm-level perspective.

The authors argue that the firm-level focus of the second wave needs to be taken to a higher level of sophistication. To properly analyze productivity growth, one needs firm-level prices with appropriate reflection of the quality of product and the conditions of demand. Raising productivity is not just a matter of improving efficiency, but raising product quality and expanding product demand as well. Firms need workers of a certain skill and managers or entrepreneurs who are willing and able to implement new ideas, tolerate risk and drive to better results.

While results vary across countries, the World Bank document finds in general that productivity growth within firms is more important than growth from reallocation between firms. Net entry is, on average, quite important, with its impact varying considerably by economy. The World Bank tested for a hypothesis that reduced dynamics in economies might be slowing productivity growth and convergence but found little evidence to support this within the developing economies studied.

A key question emerging from this research is why lower-productivity firms do not do more to emulate the behaviour of higher-productivity firms, either in their country or in an advanced economy. The World Bank authors raise the possibility without much elaboration for any country of various barriers, such as difficulty accessing capital and competition regimes that facilitate concentration. But they place most emphasis on managers and entrepreneurs that lacks the right skill set. In general, they do not have adequate education and they are risk averse.

The finding of inadequacies in managers and entrepreneurs seems to beg other questions which the World Bank document does not address. Why aren't these inadequacies being addressed, either through the managers present in these developing economies or with talent from elsewhere? Before returning to this question, it is useful to frame a key issue more simply.

Expectations of productivity convergence between developing and advanced economies were likely driven to a considerable extent by the notion that with greater exposure to world markets, lower-productivity economies and the firms within them would emulate the behaviours in the advanced economies. Certain barriers such as weak business framework policies and restrictions in capital markets could well have been expected to limit the extent of progress, but surely a good part of the productivity gap could be closed even with those conditions. With this framework, let us return to the issue of inadequacies in managers and entrepreneurs in developing economies.

If large opportunities exist – and they surely do when productivity gaps are as large as they are – why are there not natural forces that operate in favour of converge? Why do managers and entrepreneurs of developing countries not seek opportunities themselves to upgrade skills? If their home country does not offer the training required, they can access it elsewhere. Why do foreign managers and entrepreneurs and foreign firms not enter the developing economy to exploit the opportunities? Framing the questions this way would drive toward a more explicit exploration of any barriers. These barriers might then become the focal point of the study as opposed to a slavish devotion to the decompositions of productivity growth.

The authors' recommendations for future productivity research can be summarized as:

- Firm output prices and quality must be considered;
- Market concentration must be considered; benefits of productivity may not be passed onto consumers if the factors that raised productivity also increases market concentration;
- Particularly as a firm moves further into its life cycle, cultivating demand may be more important than efficiency (size matters);
- Firm production functions must be analyzed because heterogeneity in production technologies rather than a misallocation of resources may be what is holding back productivity gains;
- Quality of management and entrepreneurs must be injected into analysis as inadequacies from human capital may be the impediment to productivity gains and convergence.

  The authors assert that without considering the above dimensions, productivity research will lead to unfounded and perhaps inappropriate policy recommendations.

The World Bank's Policy Prescriptions

Having asserted that second-wave analysis puts into question traditional policy prescriptions, the World Bank report closes with a chapter advocating what appears to be a traditional set of policy recommendations. It is hard to argue against them. They have been advanced many times elsewhere. They appear logical. But they also appear quite divorced from the research presented in earlier chapters.

The overriding policy prescription is that bolstering productivity in developing economies requires strategies to bolster all three components: within firm, across firms and net exit. There is a suggestion the research supports skewing the policy agenda toward achieving gains within firm. However, it could be argued it is premature and potentially inappropriate to follow such advice. First, the World Bank study acknowledges the decomposition of productivity growth into the three components is somewhat imprecise, especially given the existing data constraints. Second, just because between firm and net entry may have been less important as drivers of productivity in certain countries, that does not suggest they do not retain considerable potential that should be tapped. Indeed, one might even turn the World Bank logic on its head and say that efforts should be skewed to these areas that have not to date proven to deliver their potential. Third, to the point made above, if the underlying factors to the three components are largely in common, focus could and perhaps should be placed on them.

The World Bank's policy prescriptions

can be summarized as:

- Improve the operating environment for firms through means such as competition policy, incentives to invest in productivity-enhancing innovation, support to improve product quality, trade expansion through opening international markets and promoting firms' sales;
- Improve human capital through numeracy, personality, managerial and organization skills, technological capabilities and organizational capabilities;
- Reduce barriers to exit and entry of new firms including encouragement of foreign investment;
- Foster a willingness and ability of entrepreneurs to experiment by creating experimental societies through actions such as correcting erratic macroeconomic policy, gearing universities and public institutions toward research;
- Raise government productivity through enhancing bureaucratic effectiveness;
- Greater policy experimentation to test what works and adapt to results as they are realized.

One can readily see that despite second-wave analysis and the claim that it "has increased the uncertainty around the impacts of traditionally recommended policies," this is a decidedly traditional set of policy recommendations. Such ideas are contained in many other documents. They have been available for consideration of developing economies for quite some time. Yet convergence in productivity toward the higher level of advanced economies is not occurring. Indeed, the World Bank authors even seem to be suggesting there may be divergence. The reader is left with a big, final question – why? For all its insights and suggestions for future work, the World Bank document does not provide much of an answer.

What the World Bank Might Have Done Differently

Better exposition will not solve the productivity conundrums, but the World Bank document certainly could have benefited from editing. There is much repetition throughout. The interesting research findings from the cross-section of developing economies are buried. This leads to generalizations even though the authors argue that results differ tremendously by country. There is an almost slavish adherence to the decomposition of productivity growth into three components despite the authors' assertion they are inextricably linked and share common driving factors. The biggest knock on the exposition is a very weak presentation on whether productivity convergence is occurring, in aggregate or by economy.

If we accept the World Bank's assertion that convergence is not occurring, then we need to keep our eye on the question of why. Such a myopic but justified focus might have led to a different kind of report. It most likely would have examined individual country's experiences much more closely and relied less on generalizations. And it would have relentlessly pursued the issue of why firms are not emulating the behaviour of more productive entities at home or abroad. This in turn would have led to a more "micro" examination of what is going on in each country. Are they implementing the recommended policy agenda? Is it falling short in critical areas? Or are the responses not as expected? In such case, as argued by the World Bank, the policy approach should react and try something different? Why aren't local managers and entrepreneurs upgrading their skills? Why aren't foreign managers, entrepreneurs and firms entering the developing countries to exploit the opportunities offered by productivity convergence. They do not need to invent a new wheel. They just need to take a wheel from elsewhere and see how it can best roll in a different environment. Do the barriers to convergence become higher the more the productivity gap is closed? Related, do flaws in the operating environment permit some productivity gains when the gap is huge but stand in the way as the productivity level in the developing country gets closer to the standard of advanced economies?

Canadian Experience in Firm-level Productivity Research

As a Canadian it is hard not to draw some analogies from the World Bank report to the situation in Canada, even though Canada is never mentioned in the report. Canada has only recently expanded and intensified research efforts using firm-level data. The experiences may be relevant to intensification of firm-level data research in developing economies. The World Bank works in second-wave analysis of productivity growth. That is, firm-level data augmented with features such as firm production functions, firm prices, quality of output, market structure and human capital. In relating this to Canada, it seems we have just recently and barely arrived at first-wave analysis. It was only a few years ago that firm-level data became available to more than a single group within Statistics Canada. Consequently, studies of productivity through the lens of firms were few and far between.[4] Most researchers took more of a "macroeconomic" perspective, focusing on the economy in total. In good part because they did not have access to the "microeconomic" data. But as well, as Canada's macroeconomic policies had been so bad from the 1970s and 1980s, creating high inflation and high interest rates, large public debt, high tax rates on capital and trade restrictions, to name just a few of the consequences, there seemed reason to think they were to blame for Canada's lacklustre productivity performance (Drummond, 2006). To use the World Bank terminology, correcting "erratic" macroeconomic policy would bolster productivity. But macroeconomic policies improved, and productivity growth did not. A point was reached where it seemed clear that more attention needed to be paid to firms and human capital (Drummond, 2011).

Firm-level data are now available to researchers outside of Statistics Canada but there remain problems: poor documentation; aggregations to protect confidentiality; a requirement until now that data work be done onsite at Statistics Canada

4 An important example of a firm-level study is Gu (2019).

in Ottawa; limited but expanding linkage to other data sets; cost recovery that comes out to around $10,000 per research project. Perhaps most seriously, a shortage of researchers interested or able to use the firm-level data to ask broader questions like those the World Bank is posing. Topics tend to be rather narrow.

In brief, it seems Canada may just recently and just barely be at first wave analysis. We would have a long way to go to tack on firm production functions, firm prices, product quality and more completely interact with human capital data.

Productivity Revisited does not discuss national Productivity Commissions tasked with developing policies to improve productivity performance through research, often with firm-level data. This is unfortunate as such commissions have been shown to focus national attention on the productivity issue, as has been the case in both Australia and New Zealand. Perhaps such an entity could play an important role to further develop the data and expand the scope of productivity research and policy recommendations in both developing countries and Canada.

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Measuring Performance and Accountability in Higher Education: A Review Article on *Productivity in Higher Education*

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Abstract

Credible and robust measurement of productivity in higher education institutions are needed to assess the accountability of the sector. This review article discusses the NBER volume *Productivity in Higher Education*. The volume contains articles estimating various facets of productivity in higher education including undergraduate outcomes from university, community college and online higher education, as well as the quality of teaching. The volume is an excellent example of combining economic reasoning with innovative data and clever analysis to yield credible conclusions. It contains important messages for the policy debate on scrutiny and accountability of Higher Education provision.

The Higher Education sector has been increasingly subject to monitoring, both across providers and for individuals within institutions. This accountability agenda is motivated by the desire to ensure improved decision making processes by the institutions themselves and by consumer and policy maker stakeholders, a laudable aim. However, such an agenda requires credible and robust measures of performance including productivity measures, but the reality has often been reliance on easy to measure indicators.

This review article discusses the volume *Productivity in Higher Education* edited by Caroline M. Hoxby from Stanford University and Kevin Stange of the University of Michigan and published in 2019 by the National Bureau of Economic Research and the University of Chicago Press. The volume employs state-of-the-art methodologies and data, and demonstrates repeatedly the dangers of using inappropriate metrics.

As a starting point for this article, it is useful to have a definition of productivity. In her chapter *The Productivity of US Post-*

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secondary Institutions, Caroline M. Hoxby defines in general terms the productivity of a higher education institution as the "value to society of its causal effect on outcomes (value added) divided by the cost to society of educating its students (social investment)". All articles in the volume try to measure 'value added', adjusting the raw data to ensure the outcomes can be attributed to the institutions and not extraneous influences, and some also attempt to measure costs.

The volume begins with an introduction by Caroline M. Hoxby and Kevin Stange, and a first chapter that outlines parallels between measuring productivity in Health Care Services (HCS) and Higher Education (HE). Together they identify four main issues that affect attempts to measure the productivity of HE institutions: multiple outcomes, selection, the multi-product nature of the institutions, and attribution. The introduction identifies a fifth challenge, the public nature of benefits, which I discuss further in my concluding remarks. This review starts with outlining the main measurement challenges and how the chapters contribute to dealing with them. I then present a summary and some remarks on the main results by chapter, followed by a brief discussion on data requirements. The review ends with some concluding remarks.

Issues in Measuring Productivity in Higher Education Institutions

Multiple Outcomes

Douglas Staiger in his Chapter *What Health Care Teaches us about Measuring Productivity in Higher Education*, argues that multiple outcomes plague measurement in HCS and that there is no easy fix for how multiple outcomes should be weighted. He warns against targeting specific outcomes as this can lead to unintended consequences for other outcomes not subject to the same level of public scrutiny. Similarly, there are many outcomes from HE, including learning outcomes, post-graduation earnings, employment, innovations and public service.

All chapters in the volume deal with multiple outcomes to a certain extent. This issue is addressed in some detail in the second chapter by Caroline M. Hoxby, where she produces productivity estimates for a number of outcomes. These include private earnings, public service measured by the difference between salaries in the private and public sectors for the same occupation, and innovation measured by R&D spend in employing firms. She shows that relative productivity varies significantly across these three outcome measures (see further discussion below). This highlights the dangers of examining one particular outcome, consistent with the warning by Staiger in his chapter.

Veronica Minaya and Judith Scott-Clayton, in their chapter *Labor Market Outcomes and Postsecondary Accountability*, investigate in some detail different outcomes, including earnings, full-time, full-year employment as a measure of employment stability, employment in social service sectors, per cent ever claiming unemployment since graduation and degree completion measures.

In Chapter 4, *An Approximation to College value Added in Two Dimensions,* Evan Riehl, Juan E. Saavedra and Miguel Urquiola attempt to measure learning as well as financial outcomes, using results from a common exit exam in Colombia. The articles in this volume show that comparisons across institutions are very sensitive to which outcomes are chosen and how they are measured. This is an important finding in a world where education, health and public service providers are increasingly being monitored by policy makers. Choosing easy to measure outcomes, such as earnings immediately after graduation, as monitoring tools may poorly reflect true differences in productivity across institutions and may encourage gaming with longer term adverse unintended consequences. Of course, researchers have been warning about this aspect of accountability exercises for decades, but this volume presents very clear evidence that this warning should be taken seriously.

Selection

Selection is the issue that has most perplexed researchers in evaluating the performance of education institutions, both schools and HE. Put simply, the post-graduation earnings of a student from Harvard University is likely to be of an order of magnitude higher than a student from a non-selective school, but much of these additional earnings are likely to reflect the innate ability of the student as well as their family and social backgrounds. Indeed, selection is also an issue in measuring HCS, as patients do not sort randomly to hospitals. In the health case, much research has been devoted to applying risk adjustment factors to raw data and Douglas Staiger suggests that adjusting for selection should be no more difficult for HE. In fact, he argues that it might be easier, as many universities have explicit admissions criteria that should permit identification of student characteristics, such as prior achievements or family background. However, there are many unobservables, such as ability, which might make the selection issue more difficult to deal with for HE. Selection issues feature in all the articles in the volume.

In Chapter 2, Hoxby uses an approach that attempts to mimic randomization while dealing with lack of overlap or common support. The latter is the problem that the 'ability' distance between highly selective and non-selective schools means there are no usable overlaps of students applying to both that could be compared. Instead she compares groups of schools adjacent to each other, using statistical paired comparison methods (PCM). Quasi-random experiments have both horizontal and vertical components. Horizontal selection, for example, selection due to the geographic location of schools, is easy to deal with by comparing students with the same application credentials choosing between two equally selective schools.

To take account of vertical selection, Hoxby considers pairs of students with the same application credentials applying to schools that are not equally selective. She uses the fact that in all admissions processes there are students who are well above the admission thresholds who are immediately accepted, students who are rejected outright and a group in the middle who can be given an offer depending on how many residual places are available. The offers in this 'on-the-bubble' range can be thought of as admissions officers flipping a coin, since there are no obvious credential differences between students in this range. Hoxby uses this middle range in adjusting for selection, and shows that this has a large impact on relative, across institution, productivity measures.

Chapter 7 by Pieter De Vlieger, Brian Jacob and Kevin Stange, *Measuring Instructor Effectiveness in Higher Education*, investigates a setting that effectively amounts to a randomised control trial where the assignment by students to instructors is random after conditioning on a number of course and student characteristics. Many chapters take a more conventional approach of using control variables to adjust for selection, as often data are not in a form conducive to mirroring random experiments. For example, in Chapter 3, Minaya and Scott-Clayton rely on regression based adjustment factors to address selection issues. Nevertheless, dealing with selection issues is a central feature of all chapters and the volume is an exemplar of how to address these issues to produce credible results

Attribution and Multi-Products

The HE sector produces multiple products across teaching programmes (undergraduate, post graduate taught, professional and doctoral programmes) and institutions vary enormously in their teaching focus. In addition HE institutions produce research and hospitality services, although these are not the focus of the volume. However chapter 6 by Paul N. Courant and Sarah Turner, *Faculty Deployment in Research Universities* examines linkages between research and teaching, both volumes and types of teaching – undergraduate versus postgraduate.

The attribution issue has always been an issue in HCS, as patients receive treatments by multiple hospitals and providers. The same is true for HE, as some students progress from two year college to four year undergraduate to postgraduate degrees, and especially in the US case, students frequently change institutions even within their primary degree. In HCS this is often dealt with by identifying health episodes that span multiple providers. In theory this could also be done for HE by tracking students across education providers. Similarly, taking from the health example, it may be beneficial to attribute outcomes to the first institution a student attends, as all other choices depend on this.

The attribution issue is dealt with in Hoxby's chapter by using lifetime earnings and all social investments. Many chapters opt to deal with these issues only implicitly, by focusing on undergraduate education and often restricting the sample, for example, to those who enter the labour market immediately after graduation. The exception is the final chapter by Scott E. Carrell and Michal Kurlaender, *Estimating the Productivity of Community Colleges in Paving the Road to Four-Year College Success*, which examines transfers from two year to four year Colleges.

Summary of Main Findings

Outcomes and Productivity in HE Institutions

In Chapter 2 Hoxby finds that, among

selective schools, value added lifetime earnings rise with the degree of selectivity of schools, but so does social investment in terms of educational resources and students' capacity to use those resources based on their ability, family backgrounds, etc. Interestingly, total social investment rises more steeply than tuition fees. This is partly due to much higher income from donations from alumni and other philanthropists as well as income from endowments, but also reflects that students in the most selective schools enrol in more curricular units and are less likely to drop out. The net impact is that productivity is relatively flat for this group of schools. She interprets this as saying that market forces operate – this part of the HE market competes both for the best students and for faculty and other resources. The implication is that taking one dollar from the most selective schools and giving it to one whose entry requirements are somewhat lower would not raise productivity of the HE sector overall. The allocation of resources to students roughly correspond to their ability to benefit from them.

This is, to my mind, a surprising result, given that, as acknowledged by Hoxby, there are many facets of HE, such as funding by taxpayers and information asymmetries, which imply market forces do not function perfectly. Partly this result is driven by the value added approach employed in the article, and highlights the need to take account of selection issues. However, the Figures in the article suggest this is not the major contributing factor. It appears that the US HE sector for selective schools is mirroring a competitive system.

When non-selective schools are compared to selective ones, however, the former have much lower productivity, and more within group variability. Here horizontal differentiation is probably more important, with students deciding according to geographic location or other amenities. Here Hoxby argues that market forces are less likely to operate as students have less information on which to base their decisions and fees are frequently paid by third parties.

When examining the other outcomes, Hoxby shows that for education contributions to public service, productivity rises with selectivity but the dispersion is much greater than that based on private financial returns. Some very selective schools have much greater productivity in contributions to public service, and this may reflect the ethos of the institutions. Market forces are unlikely to play a major role here. Finally, the innovation productivity measures show a very steep upward slope for the most selective schools. Since innovation often spills over to other workers there is no reason to expect market forces to operate. In addition the most selective schools are also the most research intensive, and so faculty are more likely to engage in research led teaching, and undergraduate programmes might be more research oriented.

Overall, Hoxby's chapter paints a picture of undergraduate education, that generates considerable benefits relative to social investments in selective institutions. For non-selective institutions, this conclusion is not so clear cut but the comparison here should arguably be relative to alternatives such as on the job training. This chapter provides a comprehensive overview of performance in HE institutions, using administrative data from tax returns linked to official reports of these institutions from the US Department of Education. It illustrates what can be achieved by combining high quality and comprehensive data sources with extensive knowledge of education systems and is a must read for anyone interested in evaluating performance in the Higher Education sector. This chapter cannot, of course, cover all aspects of HE provision, and many of the details are covered in the remaining chapters.

The context for Chapter 3 by Minaya and Scott-Clayton is the drive towards performance funding in many states. Often these rely on crude measures such as completion rates or earnings very soon after graduation. Using data for the state of Ohio, and administrative unemployment insurance records, the authors measure outcomes four years after graduation, although they include some sensitivity analysis to using shorter or longer periods, and undertake separate analyses for 4-year and 2-year degree awarding institutions. They show that there is a high degree of variability of the relative performance across institutions depending on the outcome measures – earnings, employment based measure or completion rates. Most outcome measures are highly positively correlated with the exception of degree completions, especially for the two year degree sector. Statistical compositional adjustments are more important for early outcomes, in particular for the four year programmes, but become less so as time goes on.

The general conclusion is that completion rates and early earnings outcomes, preferred by policy makers, are not good indicators of longer-term outcomes such as earnings or employability later in life. The choice of metric and the length of the follow-up matter greatly, and the longer the latter the less selection based on family background or wealth matter and the more outcomes are based on skills acquired through HE.

Riehl, Saaredra and Urquiloa in Chapter 4 use unique data for Colombia that allows the estimation of direct learning outcomes. All graduating students sit a common exit exam, which can be divided into field specific tests and reading and English that are common components across all exit exams and which partly match to entrance exams. They show that the correlation between earnings and learning outcomes are not strong, especially after adjusting for individual characteristics. Selective public institutions appear more favourable when productivity is measured in terms of learning while the best private colleges perform relatively better in terms of earnings. Consistent with the previous chapter, the authors show that results can be very different depending on how soon after graduation earnings are measured. Learning outcomes are more highly correlated with later earnings, reflecting longer term value added, whereas short term earnings are more influenced by student characteristics.

The authors also show that there are variations across fields, with engineering and business degrees showing a more favourable productivity performance in terms of earnings, and subjects such as arts and humanities performing better in terms of learning outcomes. As with the previous chapter, the authors conclude with a discussion of accountability issues, and the need for these to be designed to incorporate the findings that the choice of outcomes and the time periods over which they are measured are likely to lead to very different rankings of HE institutions.

The chapter by Altonji and Zimmermann delves further into productivity when dividing by College Major, examining both earnings and costs at a level of detail not available to date in the literature. Using data for Florida universities they show that there is significant variation in earnings across majors, which is well known, but also large variation across costs, both per graduate and per credit. Some subject areas such as engineering, with high earnings and high costs, have similar productivity to majors with low earnings and low costs such as social sciences. The results suggest that variations in costs are economically significant. This is important information for policy since it is clear that a marginal dollar spent does not have equal value in all fields. Differences can be justified if some fields such as high cost but low earnings physical sciences generate externalities, but the authors are sceptical that spillovers could be sufficiently large to account for the differences they observe. The authors also highlight changes over time, and show a reduction in costs from 1999 to 2013 in aggregate and for most majors. An interesting observation is that this is partly driven by changes in the composition of instructional resources from full-time permanent faculty to more temporary adjunct faculty. Although beyond the scope of their study, the authors point to some prior research that this may be at the cost of lower learning outcomes.

Faculty and Instructional Resources

The last point leads neatly into the analysis in chapter 6 by Courant and Turner, *Faculty Deployment in Research Universities.* Here the focus is on research intensive universities whose faculty both teach and research. The analysis is based on two public universities where the authors can access very detailed information on teaching loads and salaries. They show that there is enormous variation in salaries across fields - salary differentials largely reflect outside opportunities. However, 'costs per student' are negatively correlated with salaries. Therefore, universities vary the organization of teaching across departments to reflect input costs, leading to greater productivity. When examining interdepartmental allocations of teaching the authors show that salaries are negatively correlated with teaching load and positively with quality teaching (postgraduates versus undergraduates). The allocation of resources ensures those who are good at research make best use of their talents. Over time the authors show that salaries at research intensive universities have increased significantly, reflecting an increase in the price of research relative to teaching. The authors' results suggest that universities have responded by allocating teaching more efficiently, through larger class sizes in fields where faculty are relatively more expensive.

Instructor productivity is also the subject of chapter 7 by De Vlieger, Jacob and Stange, but in a very different setting, the for-profit HE sector. Here teaching is the only activity, and takes place both face to face and online. Based on exam results and progression across courses, the authors show that there is huge variation in instructor effectiveness. To put this in context, the variations across instructors is greater than that for outcomes for students aged 35 relative to aged 25 or those whose GPA is 2.00 relative to those whose GPA is 3.00. This is a large difference and one that the authors find is neither correlated with student's direct evaluations of their instructors or with pay, which if it varies at all, does so on the basis of seniority. This large difference in productivity of instructors suggests scope to improve student performance through personnel policies that cover how instructors are hired, retained, motivated and developed.

Online Education

Chapter 8 by David Deming, Michael Lovenheim and Richard Patterson, *The Competitive Effects of Online Education*, attempts to answer the question of how online education affects the market for HE. Online education increases choices for students, especially for those who had few prior options due to local monopolies in the non-selective or for-profit sectors. The authors exploit a change in the law in 2006 that eliminated a requirement that no more than 50 per cent of courses could be distance learning for schools that received federal aid. In a generalised difference in difference approach, the authors find that, after the expansion of online degree programs, less competitive markets experience declines in enrollments and that the impacts are concentrated in private institutions. They find little evidence of a negative impact on tuition fees in the private sector – public institutions receive heavy subsidies so are not considered – and in fact a significant positive impact for the private four year institutions. Therefore they provide evidence that these institutions do not compete in price. Instead they find that online competition increases instructional expenditures per student, and more so for public institutions who probably try to compete on the quality of the education offering, reducing class sizes and offering a better experience to students who prefer an in-person experience.

The results are robust to using internet penetration rather than degree of market concentration as their difference measure. Online degrees are often seen as poor quality in terms of learning with lower completion rates and worse labour market outcomes than traditional face to face teaching. The authors highlight an important positive from these courses, arguing that they can raise productivity and innovation in competing institutions. It will be interesting to see in the future if the move to more online delivery in all HE sectors due to the COVID-19 crisis will crowd out specialist online programs or lead to more students enrolling in them. The former could occur if bricks and mortar HE institutions are sufficiently innovative in how they blend learning to incorporate some online material but the latter may be the outcome if students do not perceive a sizeable difference in their learning experiences.

Transfer between HE Institutions

The final chapter by Carrell and Kurlaender investigates variations in the degree to which two year community colleges facilitate transfer to four year institutions (the extensive margin) and the performance of students given that they transfer (the intensive margin). The article uses rich data for California that allows controlling for student and institution characteristics. The results show very wide variation in transfer rates and in post transfer performance. The latter is measured by GPA in the first term at the four year college, the probability of persisting to year two and of graduating and length of time to graduation. The authors also present some evidence of a positive correlation between community colleges that are successful in transferring students and those where student subsequently perform well. Observable characteristics of the more successful colleges include their size, their geographical proximity to four year College campuses and a higher ratio of female faculty. The variation in productivity might reflect students preferences over amenities or location, or lack of information by students. The results are consistent with those found by Hoxby that market forces do not appear to equalise productivity for non-selective school.

Measurement and Data

The volume produced many interesting findings as summarised above. It also illustrates the powerful and robust conclusions that can be drawn when researchers have access to very good quality data. In all chapters, the analysis is based on administrative data sources, that allow tracking and matching individuals or institutions across many dimensions. This permits much clearer identification of the research question of interest, while controlling for important extraneous influences, than more traditional aggregate data sources. From across the pond, researchers can only envy the richness of the data available. That is not to say that such data are not collected in the UK or other European countries – universities collect enormous amounts of information on their students and faculty and the tax authorities collect information on graduate salaries and benefits. The main issue is difficulty of access for researchers. In Europe there are drives towards allowing greater access, but at a slow pace. However, much more work is needed in this respect, even in the United States, a point made by Hoxby and Stange in their introductory chapter.

Conclusion

This book has appeared at an opportune time, although the authors when writing were unaware of the momentous changes that inevitably will take place in Higher Education around the World, as a fallout from the coronavirus crisis. HE institutions face enormous challenges in the near future, in delivering education in safe environments and moving quickly to supplement their traditional methods using online resources, as well as likely declines in the numbers of international students. It becomes more imperative than ever to consider the productivity of these institutions.

In the opening paragraph of the introduction, the editors motivate the research by recanting a tale of HE administrators focusing solely on cost rather than benefits, which they often see as unmeasurable. This resonates with any researcher who has attempted to disseminate to policy makers/administrators the results of measuring productivity in public services or hard to measure sectors such as HE. It is very difficult to convince. Indeed, in his chapter Staiger emphasises that stakeholder buy-in is important for policy-makers, consumers and tax-payers to take seriously the productivity measures. This volume does an excellent job of dealing with the measurement issues and shows how much can be achieved by using administrative data sources coupled with knowledge of the pitfalls of using raw data and combined with sound economic reasoning.

Where the volume falls short is in measuring the wider public benefits from HE. There is a vast literature on correlations linking university education to individual outcomes such as better health and more stable family structures. Similarly, there are correlations with societal outcomes such as lower crime rates and greater civic engagement. It is much more difficult to demonstrate a causal relationship, that separates the impacts on individuals and society of higher education from other factors. *Productivity in Higher Education* is, therefore, just a starting point for a wider research agenda on the value of education. But it is a very good starting point and well worth a read.